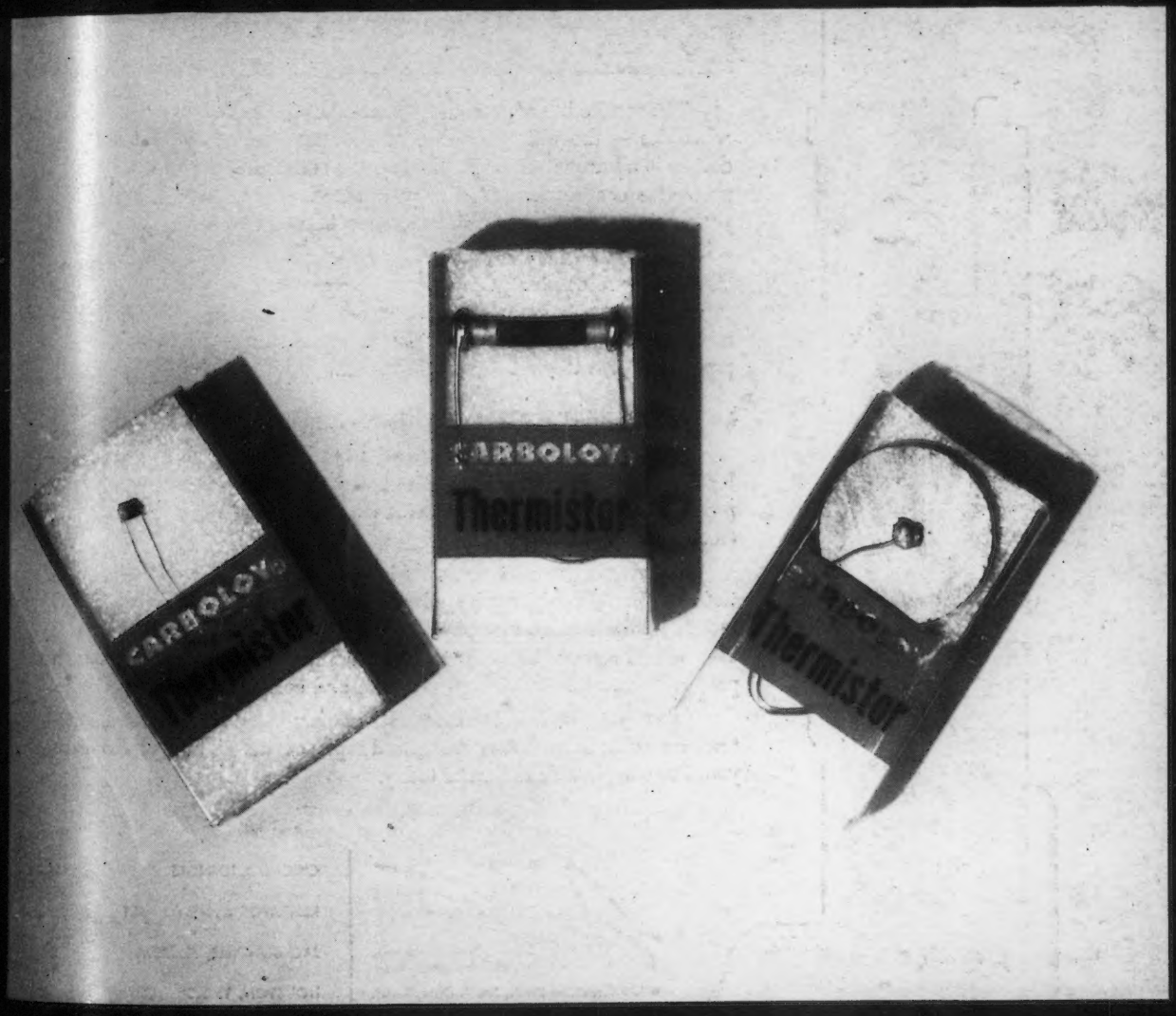
Corrosion



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Insulation Resistance, greater than (ASTM-D-257-49)	100,000 megohms	100,000 megohms
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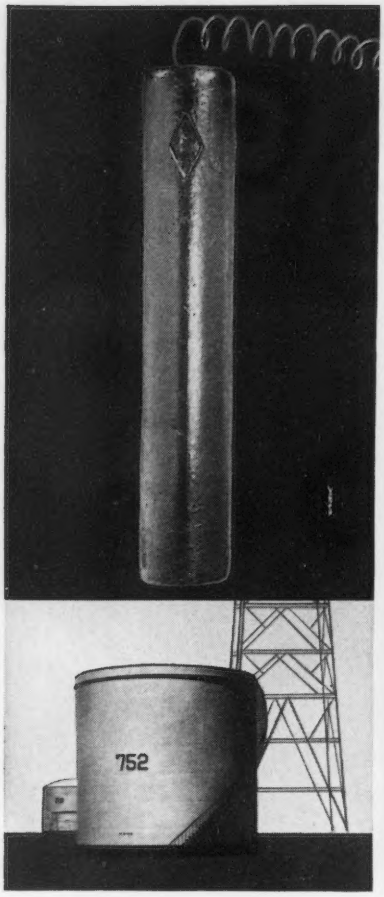

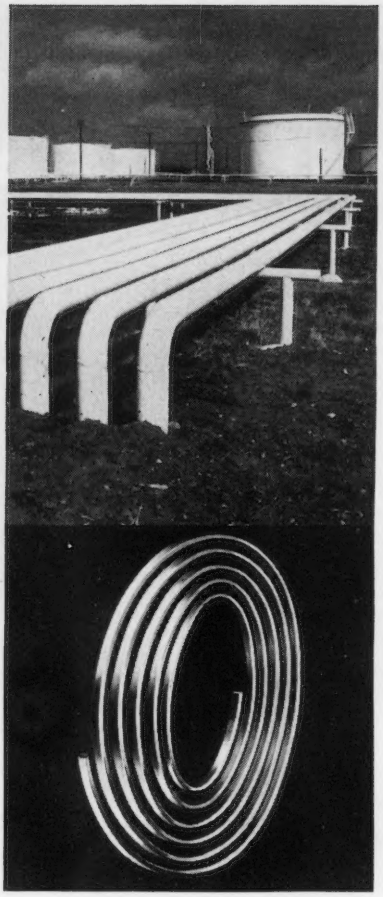

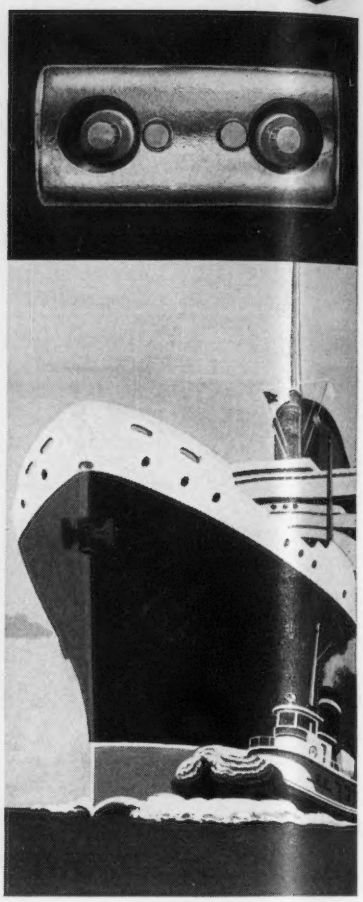

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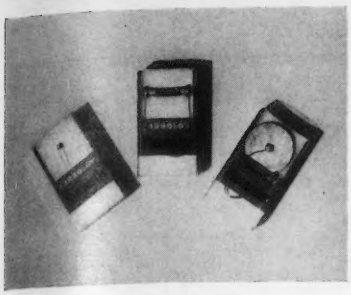

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Vol. 10 — May, 1954 — No. 5

CONTENTS

Page

Directory of NACE Regional and Sectional Officers ..... iv, v
Directory of NACE Technical Committees ..... viii, ix
Officers and Directors, National Association of Corrosion Engineers xvi

TECHNICAL SECTION

Page

Pipe Line Corrosion Committee T-2
By W. H. Stewart 141

Internal Coating of Pipe in Place
By M. B. Grove 142

Weld Seam and Weld Flux Effect on Metal Surface and Coating Life
By A. J. Liebman 147

Corrosion and Its Control in Aluminum Cooling Towers
By Sidney Sussman and J. R. Akers 151

Inspection of Petroleum Refinery Equipment
By Edward H. Tandy 160
Discussion: Arthur R. Houser, Page 163; F. W. Prange, Page 164; Replies by Edward H. Tandy, Page 164

Cathodic Protection in Florida Power and Light Company's Generating Plants
By Joseph B. Prime, Jr. 165

Effect of Exposure to Soils on the Properties of Asbestos-Cement Pipe—Final Report
By Melvin Romanoff and Irving A. Denison 169

NACE REGIONAL AND SECTIONAL NEWS

	Page		Page
Northeast, Southeast Regions to Meet May 6	3	Local Technical Group Weighed at Pittsburgh	4
Schenectady-Albany-Troy Section Loses Chairman	3	Edmonton Section	4
Greco Is Selected by South Central Region	3	Intruments Discussed at Oklahoma City	4
NACE Calendar	3	Corpus Christi Section Installs Officers	4
Tulsa Short Course Planned February 16-18	3	Pipe Line Panel, Picnic Set by Houston Section	5
Chicago Section Talks on Home Corrosion	3	Philadelphia to Honor to Past Chairmen	5
Miami Section Sees Film	3	Southwestern Ohio to Nominate Officers	5
New Officers Installed by Los Angeles Section	4	Specialty Alloys Is Sabine-Neches Topic	6
		Lehigh Valley Section	6
		Conference Report Given at Rochester	6

TECHNICAL COMMITTEE NEWS

	Page		Page
Formation of Local Technical Groups Favored	7	Bibliography on Snow Removal Methods Set	8
Officers Named for Technical Committees	7	Effect of Phosphoric Acid on Adhesion of Linings Debated	9
First Appearance of New News Feature	7	Standard for Screening Inhibitors Planned	9
T. J. Hull Named Committee Secretary	7	Long Term Tests Favored for Structural Plastics	9
In-Line Tests of Coupons Scheduled	7	Book on Corrosion of Oil and Gas Well Equipment	10
New Plastics Committee	7	Catalog of Types of Lead Sheath Corrosion	10
Scope, Organization, Objectives of High Purity Water Committee Are Given	8		

GENERAL NEWS OF CORROSION INTEREST

	Page		Page
Topic of the Month—A New Accelerated Corrosion Device *By S. K. Coburn*	1	Gordon Conference Scheduled July 19-22	12
Electrodeposition Papers Scheduled	2	1955 Officers, Directors Nominated	12
Average Attendance High at Kansas City	6	Polymeric Materials Symposium Scheduled	12
Topic of Month to Be in Technical Section	6	ASME Committee on Boiler Feedwater Gets Adams as Chairman	12
Electrochemical Society Elects Hackerman	6	Civil Engineers Organize Pipe Line Committee	12
Electrochemical Society to Meet	10	Book Reviews	14
New Correspondent for Light Metals Named	10	Pennsylvania ASM to Meet	17
Armour Foundation's Corrosion Research	11	New Products	18

INDEX TO CORROSION ASBTRACTS 21
INDEX TO ADVERTISERS 39

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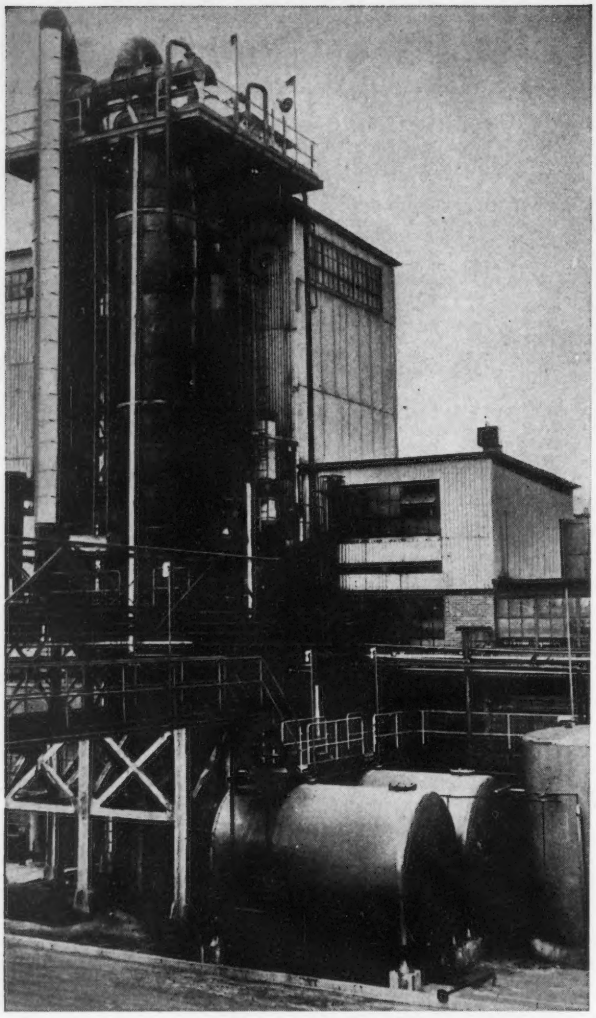
NEWS REPORTS FOR CORROSION

News reports on activities of regions, sections and other subdivisions of the National Association of Corrosion Engineers should reach Central Office NACE before the tenth of the month preceding the month in which the report is to be published.

• Secretaries who do not already have a supply are invited to ask for copies of the form "News Report for Corrosion" which facilitates making reports on meetings. Notices of future meetings will be carried in the "NACE Calendar" in the News Section when information is provided in time.

• News of meetings of corrosion interest of whatever origin are welcomed and will be carried when space permits.



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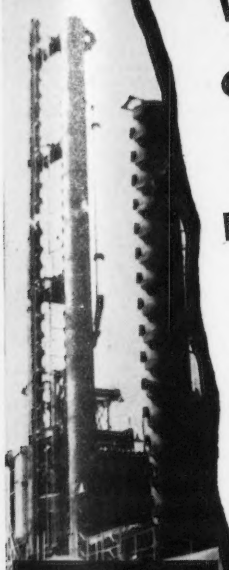

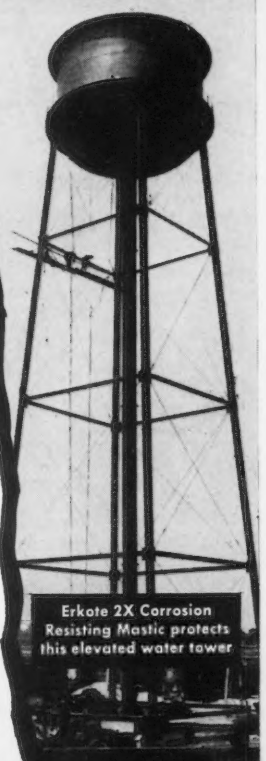

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• *T-5B-1 Exposure Tests*

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T-5C Corrosion by Cooling Waters

• *T-5C-1 Corrosion by Cooling Waters (South Central Region)*

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• *T-6M-1 Field Coating Inspection (Pacific Coast Region)*

T-6R Protective Coatings Research

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Items Are Wanted for Publication in Technical Committee News

News items are wanted from officers and members of NACE technical committees for publication in the new feature "Technical Committee News" which appears for the first time in this issue of CORROSION beginning on Page 7, News Section. This part of the magazine will be devoted to news about NACE technical committees.

The usefulness and interest of the section will be enhanced if committee members supply items which can be published in it. These should reach NACE Central Office not later than the first of the month preceding the month of publication; that is, items for the July issue should be at Houston before June 1.

A partial list of events which are suggested as suitable for publication in the section follows:

Changes of officers.

Any information pertaining to work accomplished or contemplated on reports pending, being studied, readied for publication.

Any findings of a committee related to committee work.

Changes in scope, projects, new projects, formation of new task groups.

Notices of coming committee meetings.

Reports of proceedings at committee meetings.

Requests for cooperation, new members for committees.

Announcements concerning the intention to form new committees or discontinue existing committees.

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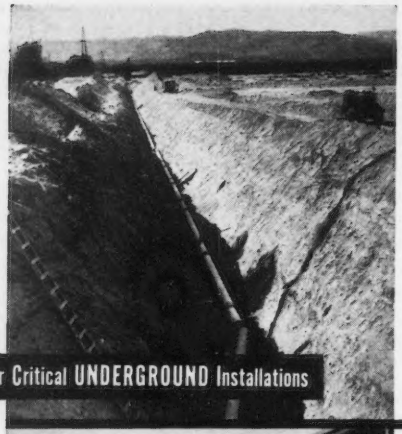

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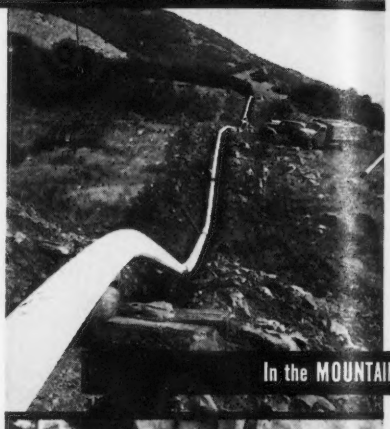

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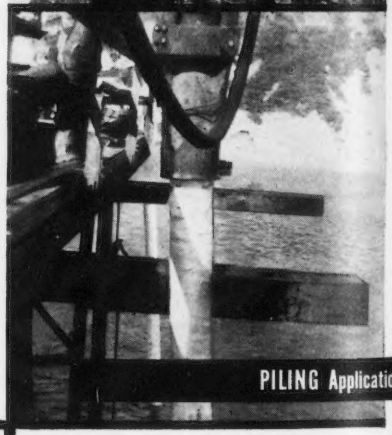

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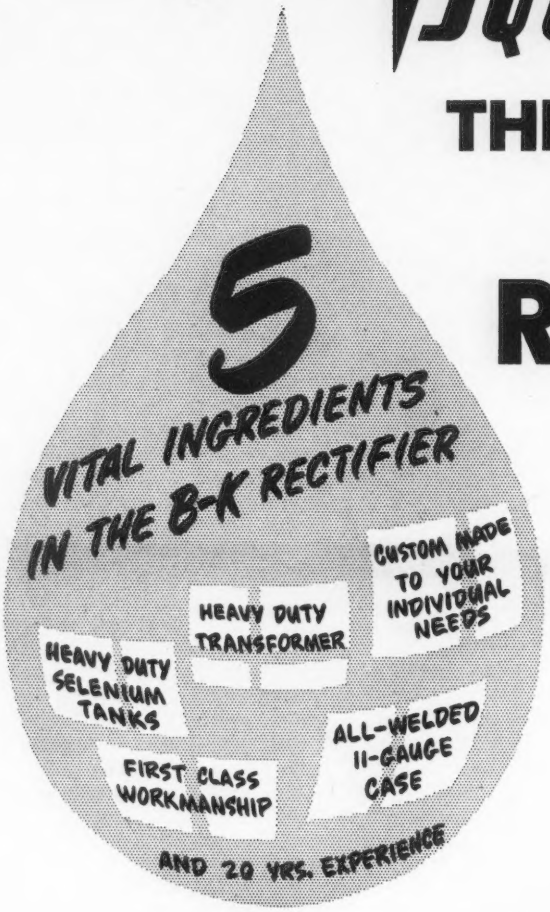

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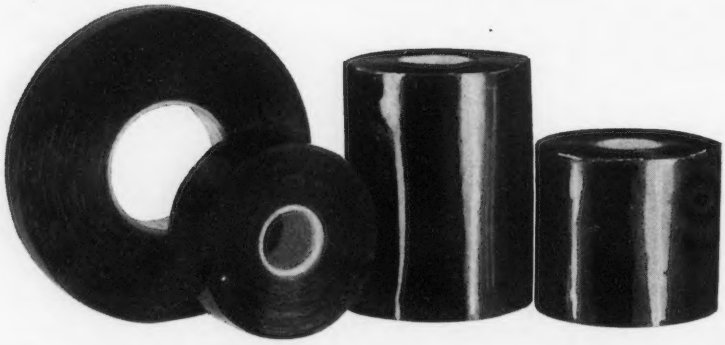

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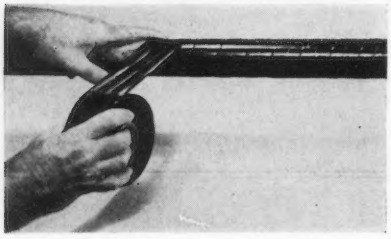

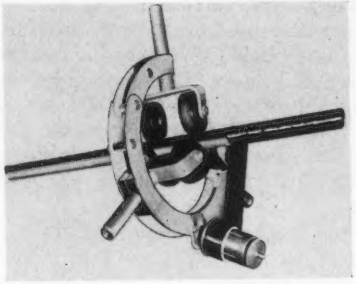

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(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

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Pipe Line Corrosion Committee T-2

By W. H. STEWART, Chairman*

AT THE 1952 meeting of the South Central Region in New Orleans, a resolution was introduced and adopted requesting the formation of a committee on pipe line corrosion similar to TP-1 on Oil and Gas well corrosion. This request was passed through proper channels of the national organization where it was fitted into the new reorganization plans for the entire technical committee set up. The need for such reorganization and streamlining had become obvious.

In the newly adopted reorganization plan, pipe line corrosion was given the designation T-2. This group committee is comprised of the chairmen of the unit committees operating as sub-committees of the above group. Each of these unit committees, together with their task groups, have under study some specific problem concerning underground corrosion or relevant subjects.

Results and reports of these studies by the unit committees will be submitted to the Group Committee T-2 for review and approval before being passed on to the Technical Practices Committee for final consideration.

The Group Committee, through its chairman submits reports twice annually to the Technical Practices Committee, thus making it imperative that unit committee work be evaluated and reported to the group committee on the same basis. The above procedure is rather clearly described in H. W. Schmidt's article "Reorganization of the Technical Practices Committee" in CORROSION, January issue.

Specifically, T-2 committee is comprised of the following chairmen of unit committees:

T-2A—Galvanic Anodes. H. A. Robinson, The Dow Chemical Company, Midland, Michigan.

T-2B—Anodes for Impressed Current. A. W. Peabody (Temporary), Ebasco Services, Inc., New York, N. Y.

T-2C—Minimum Current Requirements for Cathodic Protection. L. P. Sudrabin, Electro Rust Proofing Corporation, Belleville, N. J.

T-2D—Standardization of Procedures for Measuring Pipe Coating Conductance. W. E. Huddleston, Huddleston Engineering Corporation, Bartlesville, Oklahoma.

T-2E—Internal Corrosion of Products Pipe Lines. Ivy M. Parker, Plantation Pipe Line Company, Atlanta, Georgia.

T-2F—Internal Corrosion of Crude Oil Pipe Lines and Tanks. John C. Watts, Jr., Humble Pipe Line Company, Midland, Texas.

At present, several other units are either in the formative stage or have applied for transfer from other groups to T-2. Their work, being closely related to pipe line corrosion problems, would seem to make this desirable.

With the reporting system outlined in the new organization, it is evident that much broader dissemination of information to those interested will be the result. In the pipe line industry, the study and correlation of work from the unit committees on up through the groups to the Technical Practices Committee will doubtless prove profitable and interesting.

* Sun Pipe Line Company, Beaumont, Texas.

Internal Coating of Pipe in Place*

By M. B. GROVE*

Abstract

Procedures and results of coating internally several miles of old aluminum, steel and new steel pipe are given. The method involves scraping corrosion products from inside old pipe, descaling and drying. Coating is applied when two plugs between which coating has been poured are moved through the pipe by air pressure. Drying by air injection or aspiration follows. Economics of the lining operation are reported to be good although perfect results were not obtained with badly corroded steel pipe. Adhesion of the coating is the critical problem, even small amounts of water being conducive to separation. Coating of new steel lines is facilitated by proper design. The author suggests rigid inspection at every phase of the cleaning, drying and coating operation. At least 5 mils' thickness is recommended, this to be obtained by multiple coats, if necessary. When desiccants are used in the drying operation some means of determining when the desiccant is saturated should be employed. Better cleaning is needed, especially to remove sulfides.

LINING a pipe line in place with a plastic coating is not a new procedure. It originated with the Curtiss Tomlinson method in 1947 which means it now has service experience of approximately six years. This coating technique was developed to counter sour crude corrosion but it also has moved into the products, water and gas service fields as a corrosion control measure. The smooth surface presented by the plastic coating also has proved an aid in reducing deposition within the pipe and has found application in controlling the build-up of paraffin, carbonates and fungi. Until recently, contractors using the plastic lining in place technique were centered at Odessa, Texas, but now additional operating points have been established in other sour crude areas and further extension of service appears certain.

Plastic coating in place, like all new methods, has gone through a development stage and will continue to be improved as additional experience is gained. With this in mind, this report covers experience gained from three applications of internal plastic lining: Specifically, lining aluminum pipe, new steel pipe and badly corroded steel pipe.

Procedures of Operation

In reviewing the current procedures used by the contractors performing the cleaning and coating operation, it should be realized that certain features and equipment are patented and although the basic procedure used by all contractors—that of forcing cleaning or painting plugs through the line driven by compressed air—is the same, there is considerable variation in method and equipment among the several contractors.

A typical layout of equipment for plastic coating in place is shown in Figure 1. There is a pup joint at either end of the pipe section, one constituting a sending barrel and the other a receiving barrel for plugs put through the line. Valved openings are provided on the attached pup joints for the admission and removal of air and paint material and for installation of a pressure gauge and relief valve. Compressors are shown at each end of the line. At one end the compressor is used for sending plugs and by some operators as a source of drying air. The compressor at the receiving end may be used to backpressure the painting plugs when double plugs are used to contain the coating material, or as a source of air to be forced through a Venturi to aspirate air from the line in the drying operation. When drying air is forced through the line from the upstream position, a chamber containing a desiccant normally is inserted in the air line when humidity is high. Because of the nature of the operation, telephone or radio communication is essential among members of the crew controlling the plug movement.

Typical Job Described

A typical coating job in a line in service could be accomplished by the following procedure. Oil in the line is first displaced with water or displaced directly by successive small batches of solvent followed by small batches of alkaline detergent solution with rubber plugs separating the individual batches. The latter method is believed to provide a gas-free line safe from explosion hazards. The internal pipe surface is then cleaned by making a number of passes through the pipe with brush-carrying pigs

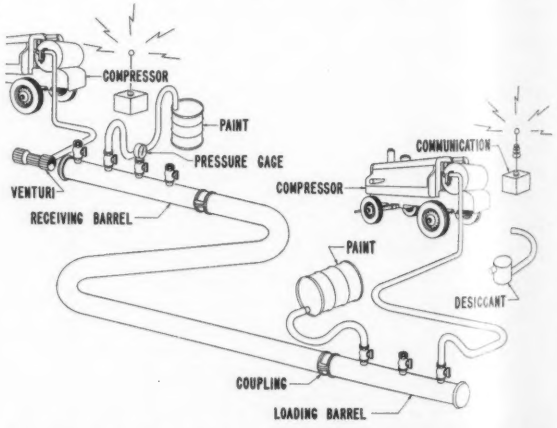

Figure 1—Typical layout for coating pipe in place internally with plastic linings.

★A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Tulsa, Okla., October 7-9, 1953.

*Senior Engineer, Pipe Line Research Section, Interstate Oil Pipe Line Company, Shreveport, La.

or metal lathe turnings normally in conjunction with solvent or alkaline detergent solutions. The mechanical scouring is normally followed by successive batches of solvent or water to wash the line clean.

The line is then cleared by running rubber plugs, sometimes accompanied by an absorbent material, such as cotton waste, and then washed with a drying agent such as methyl ethyl ketone, after which air is blown through until the internal surface is dry.

The first or primer coat is then applied, either by placing the primer in front of a rubber paint plug which is pushed through the line at relatively high speed or by inserting the primer between two counter-facing paint plugs and carrying it through the line at a controlled speed. The excess primer is removed at the downstream end of the line and the deposited coating air dried. Finish coats are applied in the same manner as the primer. Following the finish coat, the line is air dried for a matter of hours and then returned to service.

First experience of Interstate Oil Pipe Line Company with the plastic lining in place operation was in the coating of a 5-mile section of aluminum pipe in gathering service in the sour crude area of southern Arkansas. This line section was laid for experimental purposes in 1948 and operated satisfactorily until 1952, when two serious high oil loss leaks occurred. Inspections showed severe pitting had taken place internally in the bottom quadrant of the pipe generally throughout the line. As has been reported previously aluminum pipe proved satisfactory in sour crude service with the exception that steel corrosion products from upstream facilities caused severe attack of the aluminum wherever it contacted the pipe. Considering the condition of the line, it was decided that immediate replacement was necessary unless some means could be utilized for extending its service life. The decision was made to internally plastic coat the line in place following a study of the experience and economics of this protection method.

Because the internal coating of aluminum pipe was a new operation for the contractor, additional time to develop methods and techniques was provided the contractor. A one mile section was selected for the initial attempt and a 4-inch by-pass line was laid around this section so pumping could continue while the coating job was in progress. Oil in the line was displaced with water before it was released to the contractor. On receipt of the line, the contractor displaced the water and initiated the cleaning operation by running several brush pigs in conjunction with alkaline detergent solutions. This was followed by a phosphoric acid descaling solution and finally by water washes until a pH reading of about 7 was obtained. Methyl ethyl ketone was then batched through the line to remove the remaining water and after the line was air dried it was ready for the coating operation.

Furan Plastic Is Selected

A high solids furan type plastic coating was selected for this application. A zinc chromate primer containing phosphoric acid accelerator was used. The contractor's method of applying the coating was to first insert a 4-cup rubber plug in the loading barrel, pour in the required quantity of coating material in front of this plug, then place air behind the plug and let it run free at a relatively high rate of speed, carrying the coating through the pipe section. One coat of primer was applied by this method, which resulted in a relatively thin film on the pipe surface. The primer was dried for about 30 minutes by the aspirated air method, in which a Venturi was attached to the downstream end of the pipe section, replacing the receiving barrel so that air was pulled through the line. A critical step in the coating operation is the admission of a flow of drying air to the newly painted surface as soon as possible after the paint plugs have been received and the excess paint salvaged. It is interesting to note that the receiving pup joint could be removed, the Venturi attached and drying air started through the line in less than a minute after the paint salvaging operation. Four top coats of the coating material were then applied with 30-minute drying periods between them. Final drying of the finish coat was continued for approximately six hours before the line was returned to service.

Attempt Made to Coat 4 Miles

With the initial one-mile section successfully coated in less than 48 hours, it was decided to attempt coating the remaining four miles as a unit and arrangements were made for an operational shutdown of 48 hours to avoid the necessity of laying a temporary loop line. The contractor accepted this line section after the oil had been displaced with water and proceeded to clean and coat the line in the same manner used on the original section with the exception that the line was broken into one-mile sections for the drying operations.

This attempt resulted in failure because of a large undetected pithole in a flooded stream crossing. This hole admitted water from the stream into the pipe which was then pushed ahead of the primer and paint and prevented proper bonding of the coating material. It was believed at first that the water in the pipe was the result of climatic conditions, especially the extremely heavy rainfall which occurred during part of the coating operation.

A second attempt could not be made at that time for fear of exceeding the permissible shutdown period. It was not until the line was returned to service that the leak was detected. The line was repaired and about a week later three miles of this section was successfully coated using essentially the same technique as in the unsuccessful attempt. The cleaning materials, the primer and paint were pushed through the entire three-mile length and the line was broken into one-mile sections for drying. A few days later, the final one-mile section was coated successfully. Actually, the number of coats of plastic applied differed with the individual sections and was dependent and controlled by observing the quantity of the paint deposited by each coat. The furan-type coating applied by the contractor's technique required two to four top coats to secure a 5-mil thickness.

This coating has been in service a little over a

year and although two leaks have been experienced since the lining application, a recent inspection of the coating showed it to be in excellent condition. This line was not pressure tested prior to the plastic coating operation and it is felt that the subsequent leaks are the result of unusual pressure conditions rather than continued corrosion attack.

In the whole operation, 5⅓ miles of 6-inch pipe was coated at an average cost of 53½c per foot. This included the cost of installing and removing the 4-inch loop around the first section coated. The contract costs which included all labor and materials for the operation amounted to 47c per foot for the first mile section coated and 45c per foot for the remaining 4-mile section. As a comparison, the cost of laying a 6-inch line of second-hand steel pipe without external coating to replace the existing aluminum pipe is estimated at $2.12 per foot. From past experience, the estimated life of steel pipe at this location is approximately six years before expensive repairs and turning are required.

Corroded Steel Line Coated

A case selected of a coating application in a badly corroded section of steel line deals with a 4-inch field gravity line approximately 5000 feet long. This line was laid with new pipe late in 1945 and although early leak history is not available, records show that from 1949 through 1952, extensive repairs were made, the pipe was turned and approximately 10 percent of the pipe replaced. The constant repair and relacement was proving a losing battle for 22 leaks were experienced during the last year. This line was internally plastic lined in February of 1953.

The contractor accepted the line with the oil displaced and proceeded with the cleaning and coating operation in much the same way as previously described for the aluminum pipe. Surface preparation consisted of repeated runs of brush pigs; first in conjunction with a petroleum solvent and then followed with a commercial detergent solution. The line was then pressure tested and necessary repairs made. Methyl ethyl ketone was washed through the line ahead of a rubber plug and the line finally dried. This statement of procedure sounds simple enough, but actually extreme difficulty was experienced throughout the cleaning and even during the coating operation as a result of leaks behind the plugs in the line. No record of the number of leaks repaired during the cleaning operation was made but it was estimated by the company foreman who did the repairs that there were more than 50. To add to the other difficulties experienced, heavy rains forced a one-day shutdown of the cleaning operation.

Actually, because of the repeated pressure tests and repairs and the need for the operational use of the line, the coating operation was begun after a low pressure air test appeared successful and it was thought that sufficient air pressure could be maintained behind the painting plugs to assure the success of the coating application although it was known that the desired surface preparation had not been attained. As shown by a leak that occurred behind the painting plug and a subsequent leak that occurred after the line had been returned to service where, on repair, coating was found on the outside of the line, it was apparent that an oil tight line had not been secured. In the plastic lining operation, two applications of a furan-type coating were applied over the standard primer manufactured for the specific coating, by the method of placing the coating material ahead of a single plug and forcing the paint through the line. This line has now been in service nine months. Three leaks were experienced in the first four months after its return to operation with no additional leaks reported since that time. Five months after the line was returned to service, operational changes caused the removal of approximately 1000 ft. of the coated section. Inspection of the coating in the pipe removed showed that:

1. The coating appeared continuous throughout the section removed with the exception of small imperfections evidently caused by pieces of loose scale underneath and in the coating.
2. The coating material had remained tough and flexible in service.
3. The coating was considerably thicker along the bottom of the pipe than on the upper walls.
4. A few sags were observed where coating was not bonded and liquid was found under the coating with no hole apparent in the coating.
5. Considerable scale had traversed the line subsequent to the coating application without seeming to have damaged the coating.
6. Surface preparation prior to the coating application was far from rigorous or thorough enough to provide a satisfactory bond of the coating to the pipe wall. Corrosion products were found between the coating film and the pipe wall generally throughout the section observed. This foreign material was particularly noted along the bottom of the pipe and in the recesses of the pipe collars.

In view of the poor preparation of the internal pipe surface, it is rather amazing that continuity of coating was found. Even considering the undesirable findings at the time of the inspection, it was generally concluded by those who observed the section of pipe removed that the remainder of the line in service is receiving a substantial degree of protection from the plastic coating.

The contract cost for this coating operation, which included labor and material, was at the rate of 35c per foot and the average over-all cost of the operation, including direct company expense, came to 45c per foot. This is compared to an estimated cost of $1.33 per foot for replacing the existing line with second-hand pipe.

Interstate Oil Pipeline Company's experience with internal plastic coating of new pipe in place comes from a job recently completed at a main line station where 16-inch common suction-filling lines from the manifold to the tanks and the 16-inch suction line from the pumps to the manifold were coated by this procedure. This is an instance in which the existing station was being completely rebuilt and all present facilities replaced with the exception of the station storage tanks. This replacement was primarily a modernization move, although much of the anticipated reduction in operating expense should be realized by a lowering of the costs incurred as a result of corrosion.

From an internal corrosion standpoint, steps were

taken in the station design to reduce total number of lines, eliminate line stubs or dead ends and reduce low points or sags in the newly constructed lines. All tank lines and suction headers are coated internally and externally.

Although internal line corrosion at this station is not as severe as in the field gathering systems, considerable replacement and repair has been experienced. The method of recording leak experience within a station area has not been consistent in the past and only general information was available for evaluating the expected future corrosion action. Information did show numerous internal and external leaks in recent years which made necessary a general program of reconditioning and turning of the pipe through the war years and an extensive program of line replacement in 1946. Generally, it was observed that the corrosion problem was external in the vicinity of the station tankage and predominantly internal on the lower end of the lines in the suction header and manifold. Costs and advantages of internal line protection through the use of asbestos cement pipe, installation of cement lined pipe and internal plastic lining in place were investigated and the internal plastic lining selected, primarily because of its lower cost. In this case, the cost of laying cement-lined pipe or asbestos cement pipe would be somewhat higher than normal due to the terrain at this location and the necessity of evading the many existing station lines. Because the expected life of plastic lining has not been fully evaluated, this method of protection was accepted generally as a means of extending the life of the station piping some five years or more, with the opportunity of replacing the protective lining if and when necessary.

Lining Was Facilitated

To facilitate the internal lining operation, the manifold was constructed in place and the bottom manifold runs were tied into the individual tank lines prior to the coating operation. This allowed the contractor to clean and line the manifold runs in place in the same operation with the six individual tank lines. These lines varied in length with the shortest approximately 800 feet long and the longest approximately 1900 feet. Short sections of line, the manifold header and cross barrel, risers at the tanks and the suction strainer were brush coated.

The procedure used by the contractor for cleaning and coating these lines in place was as follows: Multiple runs were made with rubber plugs forcing mill lathe turnings through the line section. This was followed by one or more runs with a petroleum solvent used in conjunction with the lathe turnings. Successive wads of cotton waste were then pushed through the section until they showed the line to be relatively clean. One wash pass was then made through the line with methyl ethyl ketone and the MEK was salvaged for future use. The line was air dried by forcing compressed air which had been passed through activated alumina through the line until fumes emitted from the line were barely distinguishable. The line was then, in the terms of the contractor, "popped," which amounted to building the air pressure within the line to approximately 50 lb. and suddenly releasing the pressure by means of quick opening end release doors. The contractor uses this procedure to attain a high air velocity through the line to aid in removing dust, lint and possible remaining pockets of solvents. The primer was then applied by placing material between two double opposed rubber paint plugs. The line was pressured from the downstream end of the section, forcing the paint plugs together so that air could be bled, leaving a solid body of plastic material between the plugs. The upstream compressor was then started and the plugs moved through the line against a 5 to 15 lb. back pressure maintained by pinching a plug valve on the downstream end of the line. On receipt of the plugs and immediately after the excess paint had been salvaged, the line was bled of all air, the upstream compressor was again started and the line dried for a period of one to two hours under 40-lb. pressure maintained by pinching a plug valve on the downstream opening. The paint plugs were not removed until after the coating had sufficient time to form a tough film. Two top coats were then applied by the identical procedure used in the primer application.

Vinyl Coating Is Used

A high solids vinyl coating manufactured to the specifications of the coating contractor's requirements was used for this job. Although a minimum of five mils was specified for the total coating thickness, the contractor found that he was not able to apply single coats of primer with a thickness less than 3 mils or a top coat with a thickness less than 4 to 4½ mils by his method in the 16-inch diameter line. As a result, total thickness of coating applied ranged from a minimum of 10 mils to a maximum of 16 mils.

A few general observations are given here respecting Interstate Oil Pipe Line Company's thinking and requirements for the in-place plastic coating method based on experience to date.

1. Even on the smallest jobs, inspection should be made of each phase of the coating operation; that is, following final cleaning, the primer application and the final top coat. The number of inspection points depend on the length of the section being coated, but a minimum of three points should be prepared for observation. These points might normally be each end of the line section where the pup joints can be dropped and at a point in the middle of the line where provision should be made for separating the line or a side tapped opening of the largest practical diameter provided. The number of inspection points is controlled of course by cost of installation and the time consumed in making inspections.
2. Because of the variation of coating and cleaning application methods used by contractors, no precise specifications of set procedures have been established for the internal lining of pipe in place. Rather, bids are solicited for the individual jobs which give only the job location, operational requirements, the minimum coating thickness re-

quired, the total number of coats and the specific coating to be applied. The contractor is requested to submit his procedure for performing the work. In negotiating a contract, the contractor's letter of method is incorporated and specific exceptions are stipulated only when they involve safety and the protection of company installations. It is probable experience will make requirement of specific methods practical, particularly in the performance of the surface preparation procedure.

3. Five mils seems to have been generally accepted as a satisfactory minimum coating film. To attain this thickness, this company is now specifying a multiple coating procedure, with a minimum of the primer, if other than a wash primer and two top coats. This requirement is the result of observing some skimpy applications (especially on the top surface of the line) where the paint plug has left uncoated streaks and operations where the paint plug has moved through the line at a jumpy, unsteady rate. The assumption is made that multiple coats should aid in assuring more complete and even distribution of the plastic material. In addition, it is thought that multiple thinner coats should allow for better escape of solvents and reduce the possibility of coating holidays.

4. In the use of desiccants, in the drying operation, study is being conducted to determine when it is needed and what control needs to be exercised. All coating projects described here were performed in Louisiana and southern Arkansas, where moisture was a problem in the line. Pre-dried air was used in only one of the job operations described. In this instance, the equipment available and its capacity as a drying agent by rough calculation indicated that under the average humidity conditions in Louisiana (after taking into consideration moisture removed by the compressor and after-cooler) would allow no more than one hour's operation of the available desiccant. The amount of desiccant required and the work needed to repeatedly reactivate the desiccant presents quite a problem for a large diameter line if completely dry air is necessary in all the drying operations. In addition, care should be taken to avoid sudden release of pressure in this system through the desiccant chamber. It was noted that activated alumina was carried into the coated line section as a result of blowing stuck painting pigs from the line and careless operation of the bleeder valves during the job in which the drying agent was used. As concerns the matter of using desiccants in the drying system in future jobs, it will be required that the drying equipment be provided with proper valving and by-pass so that it can be easily removed from the system to aid in avoiding the aforementioned mishaps and that provision be made, probably using a color indicator, to show when the desiccant is saturated.

5. Looking forward to further improvements of the current internal plastic lining procedures, it is evident that a need exists for the development of better methods for cleaning and preparing the internal pipe surface. The surface condition now attained falls far short of the standards considered necessary for plastic coatings in other applications and when properly conducted is a time consuming job. Although satisfactory results are obtained with existing methods, the full value of the available coating materials could be utilized better if given the advantage of more efficient surface preparation to remove all sulfides and iron oxide scale and neutralize the corrosive action of sulfide products that appear to be retained in the metal pores.

   Also, in many instances it is desired that the cleaning and lining operation be conducted quickly so that this technique can be applied to sections of existing systems which can be shutdown only briefly. Present experience indicates there is a need for less time-consuming as well as more efficient cleaning methods, a reduction of the drying time required for the coating films and precise, systematic job planning on the part of the applicator.

6. Coating materials and coating selection is of primary interest to those concerned with this protective method. The limited period of experience of the in-place lining application has not allowed the evaluation or comparison of expected life of the coatings. Service exposure of over five years in a sour crude environment has been passed by some installations with no indication of failure. This easily justifies the use of plastic coating in a great many instances. Because all plastic materials commonly used for internal line coatings theoretically are inert to sour crude, the selection of a specific material has been primarily directed by its adaptability to the unusual application methods, drying conditions and the surface conditions presented.

   Difficulty has been experienced with coating runs and solvent wash of the coating film. From the standpoint of compounding coatings, the manufacturers have tended to tailor their products to this process by increasing the percentage of vehicle solids, maintaining a relatively high viscosity and by the use of lower boiling solvents. With these modifications, current jobs properly conducted seldom show evidence of excessive coating flow.

Summary

In summary, the internal plastic lining of pipe has been proved practical. Additional improvement in coating materials and the application methods are needed and will no doubt be forthcoming. In the crude oil pipe line industry, this protective technique is particularly applicable to sour crude gathering and lateral line service where in many cases, by comparison, an inhibitor or even a scraper program cannot be justified economically. At this time, internal plastic lining appears to be the nearest answer to the internal corrosion problem in high pressure lines of this type as well as in many low pressure lines of the larger diameters.

Figure 1—Early stage of weld flux slag, flux fume and weld spatter attack. Depending on the type of welding rod used affected area may extend from one to 8 inches on both sides of weld seam.

Weld Seam and Weld Flux Effect on Metal Surface and Coating Life*

By A. J. LIEBMAN

Abstract

Alkaline and hygroscopic welding flux byproducts deposited on weld seam and adjacent areas frequently are the cause of early failure of coatings on welds. Close observation by the author indicates many paint failures previously believed to have resulted from residual stresses in weld areas can be attributed to the effects of weld heat oxides, weld flux, spatter and weld flux fume deposits.

Careful cleaning of weld flux deposits from the weld itself and from adjacent areas either by impact tool, wirebrushing, pickling or best of all by sand blasting is recommended. A flame cleaning pass is recommended whenever moisture is present.

Extra thick vinyl pretreatment coatings followed by a mastic and finish coat are helpful in prolonging protection given metal from the environment when flux deposits are inadequately removed.

Preweld oiling of areas adjacent to welds will reduce time needed for removing flux byproducts to 25 to 30 percent of time required for cleaning areas not pretreated. Preweld oils must be compatible with paints to be used.

Grinding flat of exceptionally rough welds and weld striping to increase coating thickness are advocated.

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Introduction

WHILE STRESS CONDITIONS play a major role in controlling soundness of metal in and adjacent to a weld, the weld seam itself often is weakened by other deterioration which may result from loosening mill scale, weld heat oxide, deposits of weld flux and some types of weld spatter or by weld fume deposits. Weld fume deposits may spread the attacking agent to distances of 6 to 8 inches from the weld seam.

While preventive treatment is effective in some instances, in others it is sound and economical practice to use blast cleaning, impact tools and/or special chemical solutions to remove detrimental deposits from the weld seam and areas adjacent to it.

While the electric arc method has largely superseded gas welding and brazing, the latter still is frequently used. Several automatic systems such as spot, fusion, pressure welding and a number of others also are in common use. Of these systems, this paper pertains only to those systems which involve a fluxing agent.

Causes of Weld Seam Paint Failures

The stress effect of a weldment on the service life of coatings has long been a topic of discussion. Superficial examination of weld seam corrosion, especially when it occurs in a well painted surface, may indicate that the coating was cracked or separated from the weld by a stress inherent in the weld itself. Further analysis, however, will show that the flexibility of nearly all coating systems is such that a complete break in coating as a result of inherent weld stress is next to impossible. Because paints generally are applied to the weld surface after it has cooled sufficiently to prevent a general surface change, it can thus be postulated that changes which take place must occur at the metal-paint interface.

There are four principal reasons for coating failure about weld seams:

1. Improper removal of weld heat oxide scale.
2. A deposit of weld spatter.
3. A deposit of weld flux slag.
4. A detrimental deposit from weld flux fumes.

*A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.

Figure 2—Flux slag deposits are trapped readily in corners and in open areas especially when the hand arc weld method is used.

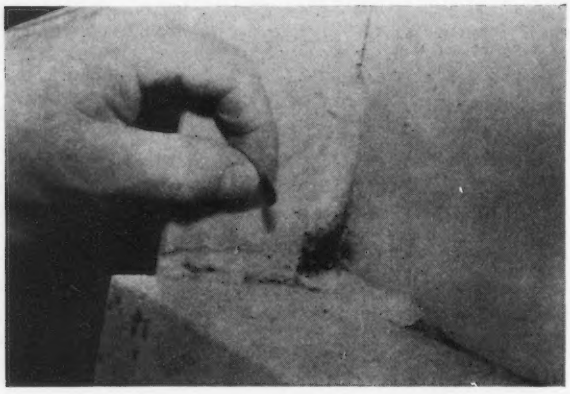

Figure 3—Even short exposure to industrial atmospheres will cause results such as this.

Figure 4—Flux slag near good open fillet welds indicated here can be removed with impact tools. A power brush cleanup and if possible a neutralizing phosphoric acid wash should follow. Blast cleaning is the best way to clean weld areas, however.

1. *Improper Removal of Weld Heat Oxide Scale.*

Weld oxide will crack and separate from the basis metal in a manner similar to mill scale and because it is even more brittle than mill scale minor impacts will separate it from the basis metal. Oxide scale may be found on both gas and arc weldments and is a result of high temperature oxidation.

Complete removal of this oxide scale by impact tools, blasting, or chemical cleaning is essential.

2. *Weld Spatter.*

Weld spatter is caused by the explosive separation om metal during welding from the common pool of metal. Spatter globules vary in size from microscopic dust to particles as big as ¼-inch in diameter and their adherence varies from tight to very loose. Because it seldom is possible to paint spatter completely and without voids as thoroughly as the basis metal is covered, early underfilm attack will be caused. The larger particles of weld spatter also may cause cracking of mill scale.

Spatter can be removed best by hand or power scraping and impact tools. Abrasive cleaning afterward also is helpful.

3. *Weld Flux Slag Deposit.*

Weld flux slag is one of the most frequent causes of paint failures adjacent to weld seams. These deposits, which frequently are deep seated, especially in hand welds, at crosses of weld seams and on fillet weldings are so difficult to remove they usually always result in coating failures. (See Figures 1 and 2.)

These deposits, being alkaline in nature[1] and highly hygroscopic are especially difficult to cope with under coating systems with relatively high vapor transmission rates. If voids are present as a result of breaks before or after painting the attack on metal will occur in practically any environment (see Figure 3) while if the slag is intact and anchored, the attack may be delayed for some time.

Separation of the paint film from the basis metal occurs when the slag deposit swells because of temperature changes or osmotic damage to the film.

Vibration also may dislodge the slag and damage the paint film. (See Figure 4.)

Localized damage from slag brings attack from moisture which expands the alkali-rich areas to adjacent areas. In some instances as much as 1/16-inch of metal may be lost per year. (See Figures 5 and 6.)

It can be removed best by impact tools, followed by wire brushing, but the best preparation is by abrasive cleaning.

4. *Weld Flux Fume Deposit.*

With all arc rods but especially when the larger diameter welding rods are used alkaline deposits of fine fume dust are made on areas adjacent to welds.

This frequently is ignored and when removal measures are taken they usually are superficial and ineffective. While wiping with a rag or removal by hand or wire brushing may produce a surface satisfactory to the eye, the result actually is that the dust is wiped into crevices where it will become active as soon as sufficient moisture penetrates the paint film to activate it. (See Figure 7.)

Brush painting frequently results in the dust being spread about and incorporated into the film so little damage results. Spray painting, however, does not have this effect.

In combination with nearby failure as a result of weld flux slag, it is a substantial contributor to early

and extensive separation of the paint film from the parent metal.

Control measures include:

1. Application of a 2 to 10 percent phosphoric acid solution which includes a wetting agent. This neutralizes the dust. Residue must be removed after application by wet rag or water spray.
2. A brush or spray coat of vinyl pretreatment.
3. When neither of the above measures is practical or economical careful wiping, brushing or scraping is urged.
4. Blast cleaning removes deposits completely.

Discussion

The discussion foregoing indicates that the stress theory is not solely applicable to loss by corrosion of metals in and adjacent to a weld seam. The author's observations indicate, on the contrary, that the weldment stresses must be sufficient to cause a separation in the metal before the paint will be affected.

The welded surface should be treated in the same way any other surface is treated prior to painting, with special attention to the greater deposits of impurities near it. How much difference this can make may be seen by comparison of Figures 7, 8 and 9.

Studies indicate good results can be expected from vinyl pretreatment, zinc chromate primers and red lead primers when the surface contaminants have been properly removed.

Extremely heavy vinyl pretreatment, followed by mastic and a top coating has been found effective in reducing damage from weld contaminants, apparently the result of the resistance of these coatings to moisture.

Washing affected areas with phosphoric acid solutions, or in some instances sulfuric acid, followed by phosphoric acid solutions, combined with wetting agents or with a proprietary treatment is a helpful precaution. When parts are small enough they should be pickled.

Impact tools frequently are used when deposits cannot be dislodged otherwise.

Blast cleaning of weld seams has been found best to remove deleterious byproducts of welding. The abrasive should range in mix from 30 to 50 mesh. In removing large sections of flux slag, spatter or other deposits the nozzle should be held at 30 to 45-degree angle to the work. A 90-degree angle is best for cleaning pits and pockets.

If flux must be removed by power brushing or hand brushing, chisels, scrapers or the like, a flame cleaning pass should follow. The flame helps to dehydrate remaining slag and to dislodge imbedded particles.

If the surface has been washed with an aqueous solution of acid or inhibitor, pockets are dried better when a flame pass is made. Likewise, flame helps in dehydrating joints or crevices after pickling.

Pretreatments to Welding

Complete or partial elimination of many of the described bad after effects of welding can be achieved by applying prewelding oil directly to the general area of the weld seam, covering a width of from one to 8 inches on both sides of the seam. Proper formulation of the oil produces the following results:

1. Adherence of weld spatter is reduced to a minimum.
2. Flux fume deposits are insulated from the metal to the extent they can be wiped off with a rag.
3. In some instances removal of flux slag is eased.

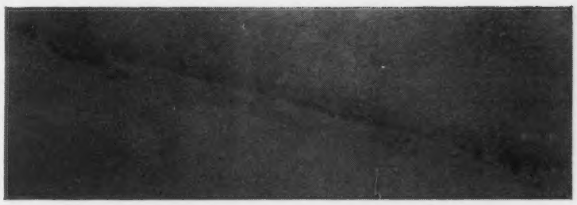

Figure 5—Flux slag, fumes and spatter and weld oxide are causing this paint failure in a humid interior environment.

Figure 6—Same butt weld seam as in Figure 5, 30 days later.

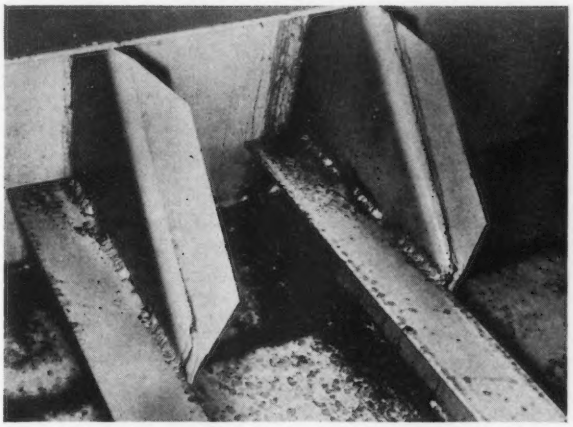

Figure 7—General weld area, including area shown in Figures 5 and 6, 60 days later.

Figure 8—Damage resulting in two years from weld flux, fumes, spatter and oxide to paint and metal.

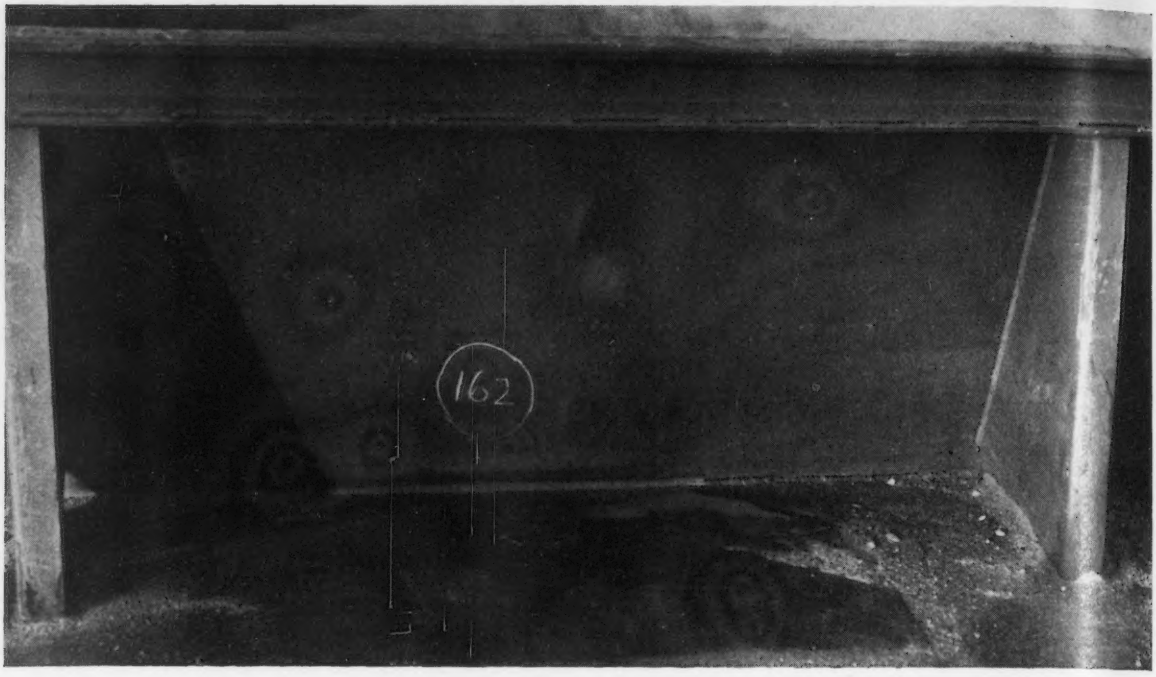

Figure 9—For comparison with Figures 7 and 8, a properly prepared surface, painted with the same paint system and approximately the same age, is shown above. Paint, as well as metal, are completely intact after two years of service.

While most preweld oils are compatible with average paint formulas the supplier of the oil should be consulted beforehand. These oils are good also in wetting badly corroded areas before painting.

Whether or not prewelding oils are used, areas adjacent to welds must be cleaned carefully. Only 25 to 30 percent as much time is needed for cleaning weldment areas when preweld oils are used as is necessary without them.

When plastic or bituminous coatings are to be used on a structure, the prewelding oils should be based in part on coating formulation.

Conclusions

Where weldments must be prepared for painting the average arc weld seam must receive more attention than is required by average structural steel. If the surface is prepared by wire brushing, some additional work is necessary to remove weld flux slag and weld spatter. Weld flux fume deposits and some of the weld oxide can be removed by brushing. Moisture left on the surface will accelerate the harmful effects of alkaline fluxing agents left adjacent to welds.

Blast cleaning will remove all detrimental deposits and provide the best anchor.

Pickling is desirable but may require additional work to remove weld spatter. Inhibiting of a pickled section is advisable.

Flame dehydrating is recommended directly after pickling or whenever there is likelihood moisture may remain in joints and crevices of the surface to be coated.

Heavy paint systems are advantageous over any weld seam. High and low spots must be covered, by a stripe coat if necessary, to increase film thickness over the welded area.

Irregular welds likely to result in thin spots on peaks should be ground to near flat.

Mastics with good adherence and vinyl pretreatments are helpful.

A phosphoric acid wash is helpful provided weld flux slag has been removed beforehand.

Preweld oils help reduce adherence of harmful welding byproducts, but they must be compatible with the coating system to be used.

Weld seam corrosion is the result of alkalinity of residual welding deposits as a rule and not of metal damage resulting from residual stress. Welding often causes loosening of mill scale adjacent to the weld seam.

Safety Precautions

Precautions to be taken from the standpoint of workers' health also help reduce fume deposits. A fume exhauster located close to the welding operation is beneficial. It should be exhausted to open air.

Fumes from paint on surfaces being welded should be removed with an exhauster. Burned coating should be removed mechanically and feathered before recoating for best long range results.

Reference

1. Walter J. Brooking. Preparation of Arc Welded Machinery for Finishing. *Metal Finishing*. 1943, Oct.

Corrosion and its Control in Aluminum Cooling Towers *

By SIDNEY SUSSMAN and J. R. AKERS

Figure 1.—Section of aluminum eliminator plate. In service two seasons in New York City.

Abstract

Data and illustrations are presented from a field study in which test coupons of six commercial aluminum compositions were immersed in circulating waters in operating cooling towers in New York, Philadelphia and Washington where corrosion has been a troublesome operating problem. Serious pitting of the aluminum occurred with untreated and improperly treated circulating waters. With correct and controlled water treatment, no appreciable corrosion of the aluminum took place.

On the basis of this study and observations of aluminum cooling towers in service, recommendations are offered for the design and operation of cooling towers made of aluminum. These include selection of the construction materials with a view toward corrosion resistance as well as physical properties, design to avoid corrosion promoting conditions, painting for protection of particularly sensitive portions of the equipment, good housekeeping and the continuous application of adequate corrosion inhibiting chemicals to the circulating water.

RAPID GROWTH in the demand for air conditioning together with increasing availability of aluminum have combined to direct the attention of consulting engineers and equipment manufacturers to this metal for the construction of evaporative cooling equipment.

Aluminum and its alloys offer a number of advantages for the construction of cooling towers. Manufacturers are interested in its ease of fabrication, resulting in reduced production costs. Consulting engineers faced with the problem of providing air conditioning for older buildings are attracted by its light weight which often permits the erection of cooling towers on roofs which are unable to carry the weight of structures made of heavier materials. Purchasers are pleased by the reduced maintenance resulting from the greater corrosion resistance of aluminum to many exposure conditions.

In common with other materials of construction, aluminum must be realistically evaluated before using for applications which place it continuously or intermittently in contact with water.

Although aluminum and its alloys are adequately corrosion-resistant in many water supplies, there are other localities where there is considerable danger of failure, not because water per se is harmful to aluminum but because these waters carry in solution the salts of heavy metals, such as copper, tin, nickel, iron, etc. These waters have a very marked corrosive and pitting effect on aluminum, especially in applications where thorough and frequent cleaning of the aluminum is impractical.

Even in communities whose water supplies are not corrosive to aluminum, these heavy metals can be picked up by the water as the result of corrosion when recirculated in evaporative cooling equipment.

Early in the planning for air conditioning installations it is important that the water supply and conditions of service be analyzed and realistically evaluated. A thorough understanding of the reactions occurring within a system will permit early establishment of sound water treatment or other protective measures. Anticipation of corrosive conditions frequently will prevent or greatly reduce the most damaging kinds of attack.

Water Conditions in Evaporative Cooling Equipment

In many parts of the country, the evaporation that takes place in cooling tower operation results in a build-up of scale-forming salts in the circulating water and the resulting scale tends to protect metal surfaces from corrosion. At the same time the typical cooling water tends to reach an equilibrium pH of 8.0-8.3 when recirculated in a cooling tower. Even

* Submitted for publication December 28, 1953.

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J. R. AKERS—Chief Corrosion Engineer, Products and Applications Dept., Reynolds Metals Company, Richmond, Va. Mr. Akers, an industrial chemist as well as a corrosion engineer, holds a BS degree from Oregon State College. He has worked for Hercules Powder Company, San Diego, 1917-18; U. S. Department of Agriculture, Summerland, Cal.; Consolidated Mining and Manufacturing Co., Mohave Desert, Cal.; Aluminum Company of America, 1919-44, and has been with Reynolds since 1944.

under such circumstances, however, some corrosion takes place and results in the appearance of small concentrations of copper, iron and other metals in the circulating water.

An especially severe corrosion situation can develop in New England, the Middle Atlantic states, the southern Appalachian region, the Pacific Northwest and certain other areas of the country where public and other water supplies are quite soft and contain low alkalinity and low total concentration of dissolved solids. Wherever such a make-up water is used in an area having appreciable air pollution resulting from industrial or urban development, corrosion becomes the principal operating troube in cooling towers and similar equipment. Spraying the recirculating water into a counter-current air stream causes the evaporative cooling equipment to act as a good scrubber for the acid gases in the polluted air. Because the circulating waters have virtually no buffering or acid-neutralizing power, they will (for example in such areas as New York City), pick up sufficient carbon dioxide and sulfur dioxide to become strongly acidic as shown in Table 1, unless chemicals are added for neutralization.

TABLE 1*

Typical Analyses of Untreated Recirculating Cooling Waters in New York City

AREA	pH	M.O.[1] Alk.	FMA[1]	TH[1]	Cl	SO_4	Fe	Cu
Times Square.....	3.3	0	35	136	18	140	12	21
Downtown West Side.....	6.1	9	0	368	43	...	1.7	1
Midtown East Side.	3.4	0	33	640	94	900	7.1	0.7
Midtown West Side	3.9	0	82	644	55	700	9.5	0.2
Penn. Station.....	4.1	0	8	280	33	...	2	26
Park Plaza.....	4.2	0	15	228	26	240	4.2	0
Brooklyn, downtown.....	5.3	33	0	278	..	...	18	2.2
Brooklyn, Ft. Hamilton.....	4.1	0	12	570	32	915	52	93
Queens, Astoria....	4.1	0	26	1000	57	770	3.6	0
Queens, Long Island City.....	3.2	0	44	680	72	520	33	2.6

* Reprinted from Reference 1 by permission of the copyright owner, the American Chemical Society.
[1] M.O. Alk.-Alkalinity, methyl orange.
FMA-Free mineral acidity.
TH-Total hardness.
Concentration, ppm (parts per million)
Alkalinity, acidity and total hardness as $CaCO_3$

Waters with pH values as low as most of those shown in Talbe 1 will, of course, corrode most metals, including aluminum and the corrosion is aggravated by the appearance of heavy metals in the recirculating water. Generally there is iron in the piping and copper alloys in the refrigerant condenser of most air conditioning systems. These metals are corroded by the acidic water as shown in an earlier study[1] and the resultant dissolved heavy metals come into contact with the aluminum portions of the system and may cause severe pitting.

One example of such action is shown in Figure 1. This is a section of an aluminum eliminator plate removed from an air washer in New York City after being in service for only two seasons. Extensive pitting has given the metal the appearance of a lace curtain. The residual salts left by evaporation of water in the corroded area contain substantial proportions of iron and copper.

Even in hard water areas, a zeolite-softened makeup water may build up sufficiently high alkalinity and pH when concentrated in a cooling tower or evaporative condenser to cause corrosion of aluminum. In one northern New Jersey community an aluminum cooling tower was corroded by a softened makeup. Analysis of the circulating water showed that the pH had risen to 9.2 and that 6 parts per million (ppm) of aluminum were present, although the makeup water was free of this metal.

In addition to dissolved impurities in the water, suspended dirt has a great effect upon the corrosion of evaporative cooling equipment. In urban and industrial areas there is a considerable concentration of dust and dirt particles carried by the air. These are scrubbed from the air by the water circulating in cooling towers and evaporative condensers. The dirt has a decided tendency to settle in the pan or basin of the equipment because the linear flow rate of water drops to its smallest value there. A layer of muck from ½ to 1-inch thick frequently is built up in the pan.

There is very little water circulation within such a dirt layer. Even if the circulating water is being treated chemically for corrosion control, the water in contact with metal under a heavy layer of muck is soon exhausted of its inhibitor and no longer can protect the metal. Conditions then become ideal for a concentration cell with consequent localized corrosion leading to pitting. Cooling tower pans must be painted for protection against this pitting. Metal cooling tower pans are painted regularly for protection from this under muck corrosion. Unpainted aluminum pans in the New York area have been corroded by this kind of action. The cause of the pitting is quite apparent because it can be observed that, in the same equipment, it is taking place on submerged horizontal surfaces in the pan, but not on submerged vertical surfaces.

These dirt layers are equally effective causes of corrosion if permitted to remain in the cooling tower after the water has been drained for a seasonal shutdown. In one such case a cooling tower was "winter-

ized" simply by unscrewing the overflow pipe and shutting off the inlet water line. When the water drained out, a ¾-inch thick layer of muck remained on the bottom of the pan. This remained damp for some weeks. When inspected later there were literally hundreds of white tubercles scattered over the surface of the dark dirt layer. When the dirt was scraped away, pit formation was observed under each tubercle.

Corrosion Tests In Untreated Waters

The growing demand for aluminum in the construction of cooling towers and the importance of controlling corrosive tendencies of recirculated cooling waters in evaporative cooling equipment, resulted in a cooperative field investigation during the summer of 1952 by technical personnel of Reynolds Metals Company and Water Service Laboratories Inc. The investigation was aimed at evaluating the effects of recirculated waters, both treated and untreated, on a selection of aluminum alloys of possible utility in the construction of evaporative cooling equipment. Test assemblies consisting of six different aluminum compositions, each carefully insulated from the others and from the supporting bolts and structure, were submerged in the basins of forty cooling towers in the New York Metropolitan area, Philadelphia and Washington. These were conventional cooling towers of steel or steel and asbestos-cement construction. Most of them were connected by ferrous piping to copper or copper-alloy refrigerant condensers.

Figure 2 shows a photograph of a typical test assembly. In order to minimize the effect of dirt settling on the specimens, these assemblies were suspended in the water with the test coupons vertical so that dirt could settle only on the very small area exposed by the edge of the specimen. Alloys selected for this test and their chemical compositions are summarized in Table 2. Table 3 presents the typical chemical

TABLE 2

Composition of Alloys Tested

(All values in %. Aluminum and normal impurities constitute remainder where not shown.)

ALLOY	Aluminum	Silicon	Copper	Manganese	Magnesium	Chromium	Zinc
61S	...	0.6	0.25	...	1.0	0.25	...
Alclad 4S (Core	...	...	...	1.2	1.0	...	...
(Clad*	...	...	...	...	...	...	1.0
99.87 pure	99.87	...	...	...	...	...	...
2S	99.45	...	...	...	...	...	...
3S	...	...	...	1.2	...	...	...

* Cladding alloy is 72S.

TABLE 3

Typical Make-Up Water Composition in Test Communities

CONSTITUENT	ppm as	New York	Philadelphia	Washington
Total Hardness	$CaCO_3$	22	127	124
Calcium	$CaCO_3$	15	79	81
Magnesium	$CaCO_3$	7	48	43
Alkalinity, Methyl Orange	$CaCO_3$	11	29	79
Alkalinity, Phenolphthalein	$CaCO_3$	0	0	0
Carbon Dioxide	CO_2	3	6	4
Chloride	Cl	2	11	10
Sulfate	SO_4	11	102	45
Silica	SiO_2	3.5	7.5	5.5
pH		7.0	7.0	7.6

Figure 2—Typical test coupon assembly (20). Note rubber grommets insulating specimens from each other and from supporting bolts. This assembly was exposed for 78 days in a chromate-treated cooling tower in Washington, D. C.

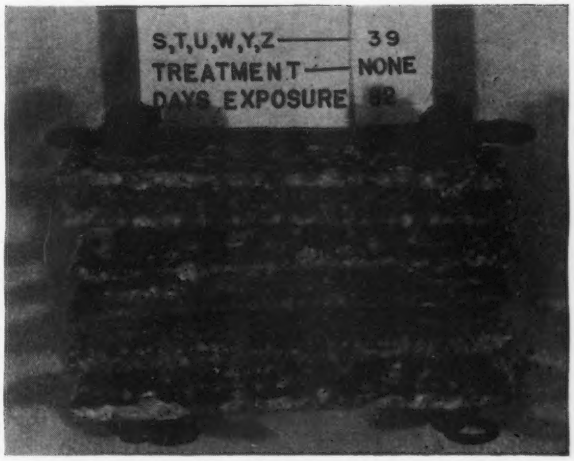

Figure 3—Test assembly (39) immersed 82 days in untreated circulating water in New York City cooling tower. Note corrosion products.

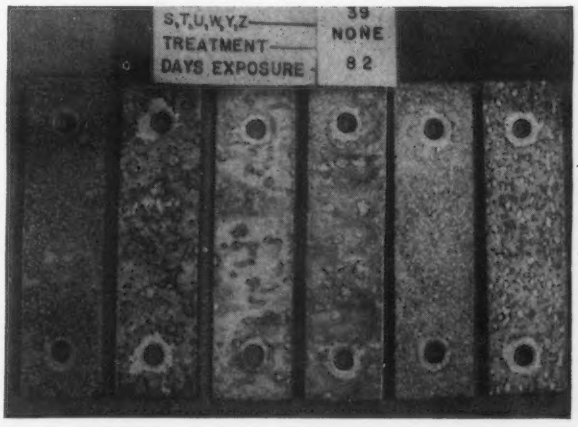

Figure 4—Test coupons from Figure 3 assembly after separation and cleaning. Note numerous pits visible.

TABLE 4—Corrosion in Untreated Waters*

CITY	Assembly No.	Days Exposure		ALLOY 61S-T6	Alclad 4S-O	99.87	2S-H 14	3S-H 14	3S-H 18
New York	66	26	MDD	7.0	6.8	4.5	6.98	5.62	5.62
			mils	3.9	2.0	19.7	6.0	7.9	6.0
New York	69[1]	60	MDD	0.31	1.31	0.66	0.31	0.91	1.20
			mils	0	4.0	19.7	0	11.7	7.8
New York	79	60	MDD	1.24	1.31	0.66	1.22	1.22	0.61
			mils	6.0	2.9	13.8	4.0	7.8	7.8
New York	80	60	MDD	3.34	1.31	3.94	4.87	3.0	3.0
			mils	20.6	4.9	25.6	15.7	11.8	9.8
New York	27	55	MDD	12.25	13.59	14.6	14.9	11.3	11.3
			mils	10.8	4.9	27.5	17.7	17.8	9.9
New York	39	82	MDD	6.68	5.25	6.48	7.77	5.55	5.55
			mils	11.8	4.0	25.5	7.9	8.9	11.8
New York	33	66	MDD	38.8	33.6	36.8	40.5	32.1	29.1
			mils	17.8	2.0	25.4	13.8	9.9	9.9
White Plains, N.Y.	75	66	MDD	6.05	7.45	3.60	4.98	5.80	6.05
			mils	17.7	4.0	29.6	15.9	13.8	6
New Rochelle, N.Y.	63	66	MDD	3.32	4.25	2.08	0.56	3.02	3.60
			mils	9.9	4.9	31.4	0	11.8	12.8
Philadelphia	43	98	MDD	2.96	3.18	2.58	2.80	2.42	2.48
			mils	10.0	6.0	27.4	19.7	17.7	10.0
Philadelphia	47	97	MDD	1.14	1.01	2.02	2.06	0.94	2.02
			mils	35.4	3.9	27.6	13.8	13.8	19.7
Philadelphia	64	84	MDD	9.80	7.90	6.55	8.45	6.95	9.95
			mils	35.4	3.9	49.0	31.6	31.6	13.7
Philadelphia	87	52	MDD	4.5	2.54	1.87	3.52	3.25	4.23
			mils	5.9	5.9	13.8	11.8	13.8	9.9
Washington	56	78	MDD	7.95	10.1	6.01	9.7	8.45	8.2
			mils	7.9	4.0	25.6	13.8	15.7	4.9

* MDD = average corrosion rate. 1 MDD = 0.000528 ipy for aluminum. mils = maximum pit depth.
1. New tower, zinc.

TABLE 5—Corrosion in Chromate-Treated Waters

CITY	Assembly No.	Days Exposure		ALLOY 61S-T6	Alclad 4S-O	99.87	2S-H 14	3S-H 14	3S-H 18
New York	85	60	MDD	0.31	0.33	0.33	0.31	0.31	0
			mils	0	0	0	0	0	0
New York	17	41	MDD	0	0.48	0.48	0	0	0.45
			mils	0	0	0	0	0	0
New York	6	93	MDD	0.39	0.21	0.21	0.20	0.20	0
			mils	0	0	0	0	0	0
Philadelphia	45	103	MDD	0	0	0	0	0	0
			mils	0	0	0	0	0	0
Philadelphia	68	46	MDD	0	0	0	0	0	0
			mils	0	0	0	0	0	0
Philadelphia	81	71	MDD	0.26	0.56	0.28	0.51	0.51	0.13
			mils	6.0	3.0	0	0	3.9	2.0
Philadelphia	83	103	MDD	0.18	0.19	0	0	0.18	0
			mils	0	1.0	0	0	0	0
Philadelphia	88	103	MDD	0	0	0	0	0	0
			mils	0	0	0	0	0	0
Philadelphia	93	78	MDD	0	0	0	0	0	0
			mils	0	0	0	0	0	0
Philadelphia	99*	65	MDD	0	0	0	0	0	0
			mils	0	0	0	0	0	0
Philadelphia	41*	65	MDD	0	0	0	0	0	0
			mils	0	0	0	0	0	0
Washington	20	78	MDD	0.23	0	0.25	0	0.45	0.45
			mils	0	0	0	0	C	0
Washington	30	78	MDD	0.23	0.25	0	0	0	0
			mils	0	0	0	0	0	0
Washington	54	58	MDD	0	0	0.34	0.32	0	0
			mils	0	0	0	0	0	0

* Treatment not by Water Service Laboratories.

composition of the water supplied in the communities in which tests were carried out. These were the make-up waters to the cooling towers and, of course, were subject to alteration by concentration, corrosion, absorption of acid gases and other factors during operation of the cooling towers.

All test assemblies exposed in untreated recirculating cooling waters in New York City, White Plains, N. Y., New Rochelle, N. Y., Philadelphia and Washington were corroded. Figure 3 shows a test assembly from New York City as removed from the cooling tower and Figure 4 shows the same test coupons after cleaning. Here, as in all these cases, corrosion took the form of pitting so that damage to actual equipment would be far more severe than the total loss of metal would tend to indicate. Corrosion in untreated cooling towers is quite rapid as may be seen from Figure 5 which shows a test assembly after only 26 days' exposure in New York. Figure 6 shows a test strip assembly from White Plains, N. Y., while Figures 7 and 8 show test coupons from a Philadelphia cooling tower before and after cleaning.

In Table 4 is summarized the data obtained by exposure of aluminum test coupons in untreated recirculating cooling towers. The average corrosion rate is given in terms of milligrams per square decimeter per day (MDD). For those more familiar with corrosion data in inches per year (ipy), 1 MDD = 0.000528 ipy. Maximum pit depth observed on each coupon is given in mils (1 mil = 0.001 in.).

One interesting fact was observed which parallels similar observations made in the study of corrosion of steel test coupons and that is the apparent inhibitive effect of zinc dissolved in water on the corrosion of aluminum in that water. Test coupons removed from new cooling towers built with appreciable amounts of galvanized steel siding or with galvanized iron piping in the surface, had only a limited number of pits. The remainder of the metal surface had an unusual dark grey or black coating which was extremely adherent and very thin. Analysis of

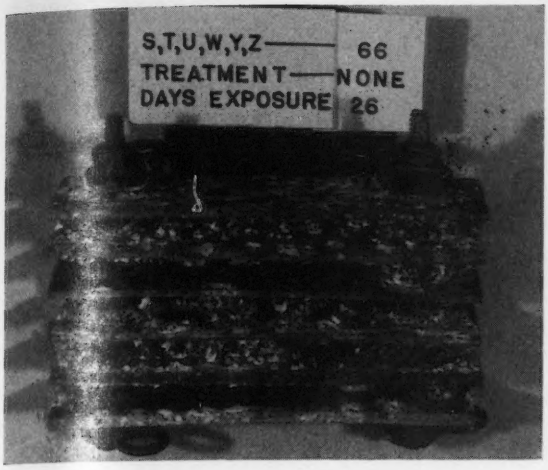

Figure 5—Rapid corrosion in untreated circulating water is shown by the extent of corrosion of this test assembly (66) after only 26 days exposure in a New York City cooling tower.

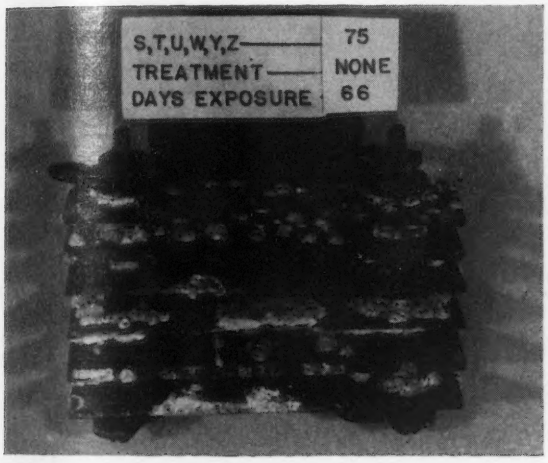

Figure 6—Test assembly (75) immersed 66 days in untreated circulating water in White Plains, N. Y., cooling tower.

Figure 7—Test assembly (64) immersed 84 days in untreated circulating water in Philadelphia cooling tower.

Figure 8—Test coupons from Figure 7 assembly after separation and cleaning.

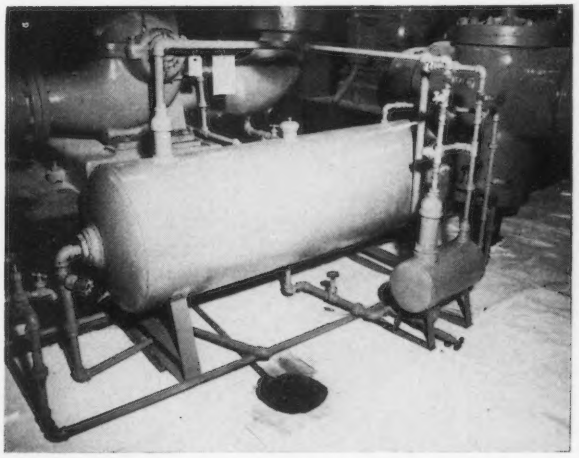

Figure 9—Carburetor Chemistat. Proportioning chemical feeder. This model is connected across the circulating pumps of a large cooling tower.

the water in such towers revealed the presence of appreciable amounts of zinc. Experience with steel test coupons under like conditions would lead the writers to expect that the inhibitory effect would continue for a few months only until most of the galvanizing had been removed from the structure and that thereafter the aluminum would act as an anode and corrode at a more rapid rate comparable with that observed in older cooling towers operating under the same conditions.

Corrosion Tests In Chemically Treated Waters

A wide variety of corrosion inhibitors are used in the treatment of recirculating cooling waters and a variety of procedures are followed in applying them. Some operators add treatment chemical once a shift or once a day, others provide for continuous addition of chemicals and still others add treatment chemicals only when they believe they are needed. The writers' experience is that continuous maintenance of a satisfactory concentration of the inhibitor is as important as the choice of inhibitor. Cooling towers used in

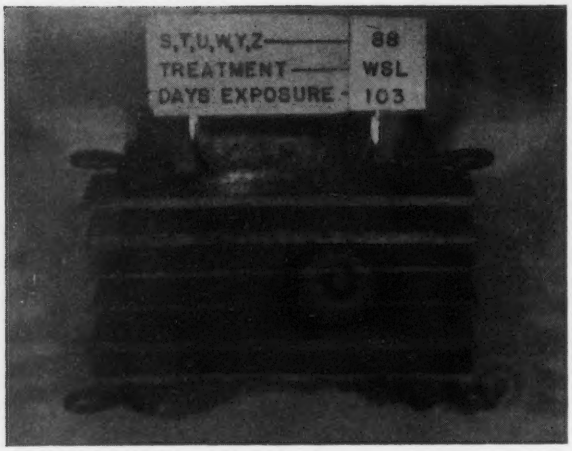

Figure 10—Test assembly (88) immersed 103 days in chromate-treated circulating water in Philadelphia.

Figure 11—Test coupons from Figure 10 assembly after separation.

testing the effect on aluminum of waters treated for corrosion control included some in which the treatment was being applied by building operating personnel and others which were being treated by Water Service Laboratories Inc. Towers handled by building personnel were being treated with a number of different inhibitors and by a variety of application methods. All of the towers under treatment by Water Service Laboratories Inc., used a continuous proportioning feeder (Figure 9) and were kept under control by periodic laboratory tests of the circulating water.

These latter installations were using pH control and a chromate inhibitor for protection of the metals. Following regular practice, the pH was maintained at 7.0-8.5 together with a 200-500 ppm sodium chromate concentration. The results of exposures under these conditions are summarized in Table 5.

Corrosion was negligible in every chromate-treated water. Most of the specimens removed from such waters still had their original bright lustre.* Note the specimens in Figure 2 exposed in Washington, Figures 10 and 11 exposed in Philadelphia and Figure 12 exposed in New York. The authors have rarely seen such distinct differences in a field corrosion experiment as they observed when comparing the aluminum samples removed from chromate-treated waters with those removed from all other locations reported in this project.

It is interesting to note that cooling towers at two of the Philadelphia locations listed in Table 5 were not under treatment by Water Service Laboratories Inc. However, analyses of water samples collected periodically at these towers indicated that the chromate treatment was being applied continuously and in an adequate concentration.

A comparison is given in Table 6 between the average penetration (inches per year) of mild steel and of the several aluminum alloys exposed in the same pieces of equipment for identical periods of time. In both chromate-treated and untreated waters, there was almost invariably more corrosion of the steel than of the aluminum. However, caution must be used in drawing conclusions from these data because, in many cases, pits were narrower and deeper on the aluminum than on the steel, so that leaks might develop sooner with the former metal in an untreated water.

TABLE 6
Comparison of Average Penetration Rates of Aluminum and Steel Under Identical Exposure Conditions

TREATMENT	Days Exposure	AVERAGE PENETRATION (Inches/yr) Steel	61S-T6	Alclad 4S-O	99.87	2S-H 14	3S-H 14	3S-H 18
None	55	0.0095	0.0065	0.0072	0.0077	0.0079	0.0060	0.0060
None	82	0.0117	0.0035	0.0028	0.0034	0.0041	0.0029	0.0029
None	60	0.0053	0.0007	0.0007	0.0003	0.0006	0.0006	0.0003
None	84	0.0113	0.0052	0.0042	0.0035	0.0045	0.0037	0.0052
None	78	0.0050	0.0042	0.0053	0.0032	0.0051	0.0045	0.0043
Chromate	93	0.0010	C.0002	0.0001	0.0001	0.0001	0.0001	0
Chromate	60	0.0004	0.0001	0.0001	0.0001	0.0001	0.0001	0
Chromate	78	0.0003	0	0	0	0	0	0
Chromate	58	0.0009	0	0	0.0002	0.0002	0	0

TABLE 7—Corrosion in Polyphosphate-Treated Waters

CITY	Assembly No.	Days Exposure		ALLOY 61S-T6	Alclad 4S-O	99.87	2S-H 14	3S-H 14	3S-H 18
New York	2	41	MDD	0.89	0.48	0.48	0.45	0.45	0.45
			mils	2.0	4.0	0	0	0	0
New York	15	93	MDD	6.45	6.75	4.90	5.90	5.35	5.25
			mils	24.0	3	21.6	21.6	13.8	13.7
Philadelphia	94	77	MDD	10.7	12.0	10.75	10.75	10.2	11.1
			mils	28.6	4.0	25.6	13.8	30.6	15.7
Washington	1	52	MDD	3.38	2.64	6.0	1.94	1.76	2.8
			mils	19.7	5.9	39.4	19.7	13.8	9.9
Washington	12	78	MDD	0.23	0.25	0.25	0	0.23	0
			mils	0	0	0	0	0	0
Washington	65	78	MDD	1.17	2.25	0.75	1.64	0.94	0.94
			mils	19.6	5.0	7.9	3.9	8.8	3.9

* This includes a group of specimens exposed in a chromate-treated New York cooling tower for 321 days.

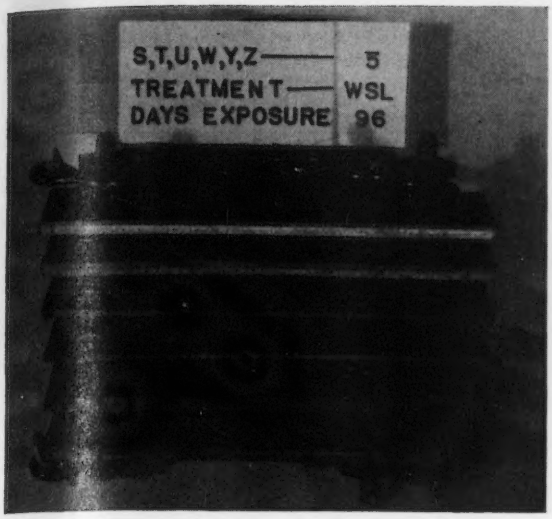

Figure 12—Test assembly (5) immersed 96 days in chromate-treated circulating water in New York City.

Figure 13—Test assembly (1) immersed 52 days in polyphosphate-treated circulating water in Washington.

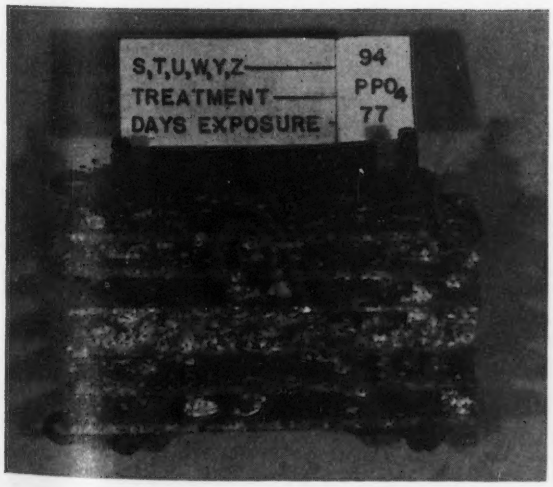

Figure 14—Test assembly (94) immersed 77 days in polyphosphate-treated circulating water in Philadelphia.

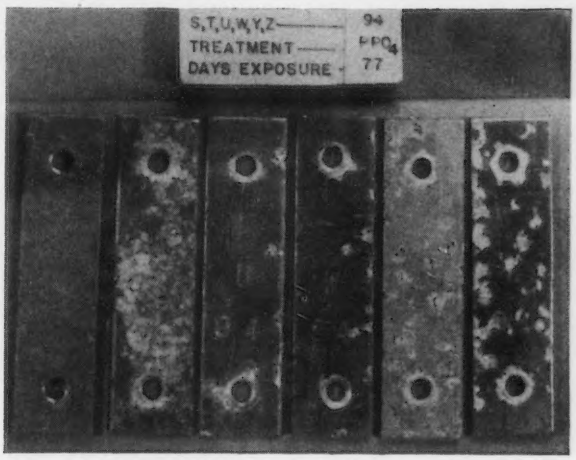

Figure 15—Test coupons from Figure 14 assembly after separation and cleaning.

Figure 16—Test assembly (15) immersed 93 days in polyphosphate-treated circulating water in New York City.

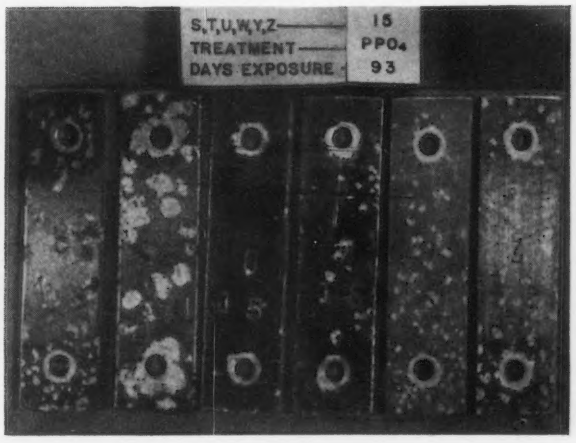

Figure 17—Test coupons from Figure 16 assembly after separation and cleaning.

Figure 18—Test assembly (4) immersed 126 days in organic-treated circulating water in New York City.

The polyphosphates, such as sodium hexametaphosphate ($NaPO_3$) and others, are frequently used for corrosion control, as well as scale control. Test coupons installed in a number of polyphosphate-treated cooling towers showed a wide variation in the degree of protection obtained. The corrosion data are summarized in Table 7. Specimens from polyphosphate-treated cooling towers are illustrated in Figure 13 (Washington), Figures 14 and 15 (Philadelphia, as removed and after cleaning), and Figures 16 and 17 (New York, as removed and after cleaning). Analyses of water samples taken at these test locations showed uneven application of the treatment chemicals and, therefore, it is difficult to say whether the failure to obtain adequate corrosion inhibition indicated improper application of the treatment chemicals or inability of the polyphosphate to protect aluminum.

A number of organic materials have been offered to users of recirculating cooling water equipment as inhibitors of both corrosion and scale formation. In Table 8 is summarized results obtained by exposure of aluminum test strips in two cooling towers which were treated with a tannin extract which has been widely offered in the New York and Philadelphia areas as a corrosion inhibitor. The data obtained indicate poor protection. Figure 18 shows the test assembly exposed in New York.

Silicates also are used as corrosion inhibitors. Although some of the test strips exposed in two cooling towers being treated with an alkaline silicate were pitted, because of the limited number of tests realistic appraisal of the effects of this inhibitor on aluminum is not practical at this time.

In order to make comparison of their resistances easier, a rating number was assigned each alloy under each of the exposure conditions. The rating number was related to maximum penetrations found. These data are in Table 9.

TABLE 9
Relative Resistance of Specimens to Pitting
(Lowest number indicates least pitting)

Water Treatment	61S-T6	Alclad 4S-O	99.87	2S-H 14	3S-H 14	3S-H 18
None	5	1	6	3	4	2
Chromate	6	4	1	1	4	3
Polyphosphate	5	1	6	3	4	2
Organic	3	1	6	4	5	2
Silicate	3	1	6	4	5	2
Average	4	1	6	3	5	2

A rating of one indicates that an alloy showed minimum total penetration under the test conditions indicated. Relative ratings given for specimens in chromate-treated waters are largely meaningless because the pit depths were too small and scattered to be significant. Therefore, in preparing the average ratings, these data were omitted.

Under all exposure conditions except chromate treatment, the Alclad specimen, as might be expected was the most resistant. The consistency of the 3S-H18 in No. 2 position also is noteworthy. Presumably an Alclad 3S or Alclad 4S would make a very desirable material for construction of cooling tower surfaces which come in contact with circulating water. The choice would depend on the physical properties required.

Recommendations

From the results of this investigation, it is apparent that three factors are of prime importance in the use of aluminum for the construction of evaporative cooling equipment.

First, the proper alloy or alloys must be selected for various elements of the equipment and sound design principles must be used to avoid situations which may tend to promote corrosion. As mentioned above Alclad 3S and Alclad 4S appear particularly suitable for water contact surfaces on the basis of this corrosion study. Contacts between dissimilar metals must be avoided. Less obvious construction errors also can promote corrosion. In one case the pan of an aluminum cooling tower was of rather light gauge metal and lacked sufficient structural support. The pan sagged so that the drain was not at the lowest level. During operation dirt settled in the valleys and, when the pan was drained, water remained behind there. Both of these factors led to rapid localized corrosion at the low points.

Second, the equipment must be properly maintained. With aluminum as a construction material, it is particularly important that the equipment be cleaned regularly. Contact between the aluminum and other metals, particularly copper, must be avoided. The pan should be inspected regularly for tramp metal

TABLE 8—Corrosion in Organic-Treated Waters

CITY	Assembly No.	Days Exposure		ALLOY 61S-T6	Alclad 4S-O	99.87	2S-H 14	3S-H 14	3S-H 18
New York	4	126	MDD	1.59	1.55	1.09	1.16	1.31	1.16
			mils	13.8	4.0	17.8	21.6	17.7	11.7
New York	18	37	MDD	1.97	3.70	2.12	1.92	1.92	2.46
			mils	11.8	4.0	17.7	6.0	17.7	11.8

or pieces of wood in contact with the aluminum. Both of these can promote severe localized corrosion.

Even repairs must be carefully checked from the corrosion viewpoint. One aluminum cooling tower pan corroded through because a copper screen was installed on the pump suction. A rubber connection was used leaving the cylindrical copper screen lying on the bottom of the pan in direct contact with the aluminum.

Painting of the pan or basin interior and other horizontal surfaces on which dirt can readily settle is necessary for minimizing concentration cell corrosion. The metal surfaces must be properly cleaned and prepared before painting. All sediment and corrosion products must be removed and any traces of grease or oil must be removed by a solvent wash. Surface preparation should include a phosphoric acid-type wash primer, followed by a zinc chromate primer and a finish coat. The finish coat may be any good waterproof paint or bituminous coating which will resist water, mild acid and alkali.

Third, the circulating water and make-up water should be analyzed by competent water specialists and, if they so advise, a suitable corrosion inhibitor should be continuously applied in adequate concentrations. On the basis of the present work the use of 200-500 ppm sodium chromate with pH control at 7-8.5 is particularly effective in minimizing corrosion. A regular testing procedure is required for control of the inhibitor.

Conclusions

Aluminum has many outstanding characteristics that will prove beneficial in the construction and operation of cooling towers and similar equipment. Light weight with strength, ease of fabrication and good general corrosion resistance are important properties of aluminum for this application. Selection of the correct alloys and the use of sound design principles, regular maintenance and continuous controlled treatment of the circulating water will insure satisfaction and good service with aluminum equipment.

Reference

1. S. Sussman, *Ind. Eng. Chem.*, **44**, 1740-44 (1952) Aug.

Inspection of Petroleum Refinery Equipment*

By EDWARD H. TANDY

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Abstract

The conditions created by the presence of corrosive compounds in crude oils, the formation of corrosive compounds during processing and by the use of corrosive process chemicals makes constant inspection of refinery equipment necessary. The refinery equipment inspector must be familiar with construction and operation so he can anticipate and forestall expensive replacements. Corrosion caused by hydrogen sulfide formed during distillation by the breakdown of sulfur compounds usually can be predicted. However, the inspector always must be alert for localized overheating which will accelerate the corrosion rate. Naphthenic acids are most corrosive at their condensation points. Their presence in the crude oil or their formation during refining may cause severe localized corrosion wherever they are condensed or evaporated. Corrosion in gasoline storage tanks caused by moisture, oxygen and slight concentrations of other gases, proceeds at a low rate as compared to corrosion in distillation equipment. Nevertheless, it is responsible for major repairs.

Introduction

CORROSION is an ever present threat to petroleum refining equipment and accounts for a substantial portion of maintenance and replacement costs. In addition to the soil and atmosphere, the corrosive media vary from chemicals which are used as part of the process to compounds in the crude oil which are corrosive in themselves or break down into corrosive compounds. Strong acids such as sulfuric and hydrofluoric are in common use as process chemicals as are strong caustics and organic amines. The crudes contain varying amounts of hydrogen sulfide and sulfur compounds as well as a number of organic acids. All of these can be and are handled safely under controlled conditions with the right materials. However, because of possible severe consequences if a failure should occur, every piece of equipment in the refinery must be inspected at regular intervals to be certain that corrosion doesn't get out of hand.

Years ago the refining of crude was a rather simple process. It consisted of heating the crude in a fired steel batch still at about atmospheric pressure, or under a vacuum, to about 600 degrees F and condensing the vapors driven off in a submerged cast iron condenser coil. The condensate was stored in steel tanks and later treated as necessary with sulfuric acid in lead lined equipment. Corrosion was not particularly severe and its detection was fairly easy because the equipment was simple. Often, inspection consisted of simply waiting for a leak to show up and then shutting down the equipment involved for repairs. In a modern refinery the equipment and processes are much more complicated and the failure of a minor part might shut down an entire unit. There have been some instances in refineries where costly fires have resulted from minor failures. Process temperatures now range from minus 100 degrees F to more than 1100 degrees F while pressures vary from 26 inches Hg vacuum to as much as 3000 psi. It is no longer economical or safe to wait until some piece of equipment fails before shutting down a plant for repairs. Inspection and maintenance must be carefully planned in advance to balance with stock commitments, fouling and expected life of the equipment, availability of manpower and many other things.

Inspection Requirements

Each piece of equipment in the refinery must have some sort of an inspection at regular intervals. The intervals range from a few weeks to as much as 10 years. The inspection frequencies are established from past experience with the equipment or in the case of new plants they are based on information gained from similar equipment or processes. These frequencies are revised from time to time depending on the accumulation of more complete data or on changes in operating conditions. The scope of the inspection may vary from a simple visual inspection or hammer test to a very thorough inspection of all parts. The thoroughness of the inspection will depend on the length of time the equipment has been in service, its past history and the history of similar equipment and the hazards involved. Obviously a knock out pot handling a mildly corrosive stock at atmospheric temperature and pressure will not receive the same attention as a fractionating column processing a very corrosive stock at 300 psi and 850 degrees F. The type of inspection made may depend on what happens in other parts of the country. For instance, after the failure of a sphere in the East, a magnetic particle inspection of the welds in all spheres was made to be sure that equipment at El Segundo would not be subject to a similar failure.

To be certain that all equipment is systematically inspected at regular intervals there has been established an Equipment Inspection Section as part of

* A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953. It includes part of the material covered in a paper titled "Some Corrosion Problems in Petroleum Refinery Operation," given at a meeting of Western Region, NACE, November 20-21, 1952.

the Refinery Engineering Division. Its function is to schedule and make the necessary inspections at the proper intervals, to record and analyze corrosion data and to keep a record of the life and service history of the equipment. It also compiles data on the materials used for construction and repair. To do this the inspector must have a fundamental knowledge of the chemistry of the process and the operating conditions of the plants he inspects as well as an intimate knowledge of the individual pieces of equipment. He needs to understand the chemistry of corrosion as well as being able to ferret out its effects. The increasing use of heat and corrosion resistant alloys requires acquaintance with practical metallurgy for a better understanding of fabricating and maintenance practices and their relation to subsequent corrosion phenomena.

Observed Corrosion Rates

In any piece of equipment where corrosion is involved, the corrosion rate is calculated from gage measurements of established gage points or from actual thickness measurements at each inspection. Since the apparent corrosion rate for any one period is an average for the conditions during the last run, a careful check must be maintained on the results for each run and for the overall operating life. Operating conditions and the stocks processed vary from time to time and sometimes a small operating change can cause a substantial increase or decrease in the corrosion rate. In a combination crude distillation unit some equipment changes were made that permitted a 20 percent increase in feed rate. During the next run of about six months the corrosion rates throughout the plant showed a noticeable increase but were not severe. At the beginning of the following six months run the operators found that an additional 1 percent increase in feed rate could be made by increasing the outlet temperature of the atmospheric furnace 10 degrees F and making some other minor adjustments. This latest operating change was responsible for a major change in corrosion rate in the atmospheric furnace. At the end of the run the 5 percent Cr Mo tubes in one part of the furnace were corroded to minimum thickness. Prior to the latest increase, these tubes had suffered some pitting and cavitation at the inlet ends only which were easily protected by installing short sleeves. Now, however, the entire length of the tubes were severely pitted and the corrosion rate was so high (about 0.020-inch/1000 hrs.) that it was necessary to replace them with 18-8 Cr Ni tubes. Because of the nature of the crude processed in this unit, corrosion always has been a major problem. The crude contains salts which break down to form hydrochloric acid in the atmospheric overhead system; it contains sulfur compounds which cause corrosion by hydrogen sulfide throughout the plant and it contains naphthenic acids which cause considerable corrosion in the vacuum side of the plant. Naphthenic acids are particularly bad actors and produce some starting results as will be noted later.

One of the most common corrosives in a petroleum

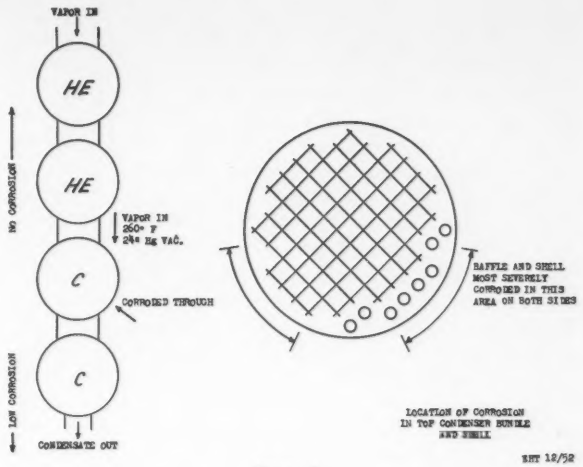

Figure 1

Hydrogen Sulfide Corrosion

refinery is hydrogen sulfide. It may be brought into the refinery as an absorbed gas in the crude oil but it is more usually formed in the refining processes by the breakdown of sulfur compounds in the crude when it is heated to 400 degrees F or more. Unfortunately, the first heating of the crude does not break down all of the sulfur compounds to hydrogen sulfide. Other intermediate sulfur compounds are formed which are drawn off in some of the cuts or fractions of the crude that are used to make the various products. Subsequent heating of these fractions usually will produce more hydrogen sulfide. At low temperatures hydrogen sulfide is not particularly corrosive and is easily controlled. On carbon and low alloy steels the corrosivity of hydrogen sulfide increases rapidly above 500 degrees F and reaches a maximum at about 900 degrees F. Above this temperature hydrogen sulfide corrosion stops. Corrosion rates on carbon steel of 0.002-inch/1000 hours at 500 degrees F and as much as 0.250-inch/1000 hours at 900 degrees F have been observed. The rate, of course, depends entirely on the conditions. So long as the operating conditions are known, one can predict the corrosion rate fairly accurately and act accordingly.

Feed stock for thermal reformers contains sulfur compounds that break down to form hydrogen sulfide upon heating. A problem involving an accidental change in operating conditions will illustrate why inspectors must be constantly alert. The tubes in the wall coil of a reformer were 1¼ percent Cr Mo and from gage measurements taken over a fairly long period of time the corrosion rate was pegged at 0.006 to 0.008-inch/1000 hours with an eccentricity factor of 60 percent. Furnace tube surfaces exposed to radiant heat usually will corrode faster than the surfaces away from the fire. The eccentricity factor indicates the difference in corrosion on the two sides. In this case 60 percent of the total increase in inside diameter is caused by corrosion on the hot side and 40 percent by corrosion on the cold side. As a result of routine inspection a number of tubes in the lower wall coil were found excessively scaled externally

and one was cracked. The tubes were all gaged and found to have higher than normal increases in inside diameter. These tubes had all been gaged one year previously and the indicated remaining life at that time was about six years. Because of the sudden increase in inside diameter, several of the tubes were removed and sectioned for investigation. All were found excessively thinned on the fired side. The corrosion rate had jumped to 0.025-inch/1000 hours (about 4 times normal) and the eccentricity factor had increased to 72 percent. A total of 14 tubes were removed, all of which had higher than normal corrosion rates and eccentricity factors. The area of accelerated corrosion was a circle about 12 feet in diameter near one end of the furnace. Outside this circle the conditions were normal on all tubes including the ones removed. One of the burners was found cocked and poorly adjusted which resulted in flame impingement on the tubes in the corroded area. The overheated tube surfaces caused localized high stock temperatures of the inner surface and, of course, the accelerated corrosion.

Naphthenic Acid Corrosion

Naphthenic acids, which are present in some crudes or are formed during processing, cause considerable trouble. Their boiling points are in the same range as many of the crude fractions and as a result they are often concentrated and cause severe corrosion. Equipment processing stocks containing these acids must be inspected carefully because it is difficult to predict where the corrosion will occur and there is usually no scale formed. The corroded surface of carbon steel and cast iron is smooth, almost slick, and it is often difficult to determine if any appreciable wall loss has taken place without actual gage measurements. The surface of low chrome steels, on the other hand, is severely pitted and is usually penetrated at a higher rate than carbon steel. Type 304 Cr Ni under some conditions has an appreciable corrosion rate. The surface usually is roughened and has the appearance of a deep etch. Type 316 Cr Ni Mo usually is not affected. These acids are most active at their boiling points but the most severe corrosion generally occurs on condensation. Corrosion rates as high as 0.030 to 0.040-inch/1000 hours have been observed on carbon steel. The rate drops very rapidly as the temperature drops below the boiling point. For carbon steel the corrosion rate may be as low as 0.002 to 0.003-inch/1000 hours 20 degrees F below the boiling point of the acid. In the vapor state there is practically no corrosion.

It should be interesting to illustrate how these acids sometimes produce unusual effects by a problem which occurred in a combination crude distillation unit. The vacuum overhead system of this unit consists of two parallel vapor streams which pass through two heat exchangers and two condensers in series. The stock, which is a heavy gas oil vapor, enters the top condenser at about 260 degrees F and 24-inch Hg vacuum (See Figure 1). The shell of one of the top condensers was found corroded through after operating a little over one year. The tube bundle was removed from the failed condenser and it was found that the transverse baffles were severely grooved and corroded in the lower half of the bundle, particularly around the outer part. The lower third of the shell had deep circumferential grooves, one of which was corroded through. The indicated corrosion rate at this point was 0.020-inch/1000 hours. The upper half of the shell was only lightly etched. The heat exchanger above had no corrosion. The downcomer between the upper and lower condenser shells was heavily etched but there was no material loss in thickness. The shell, tubes and baffles of the lower condenser were not affected. The tube bundle was removed from the upper condenser in the parallel stream and the same conditions were found. Having had considerable experience with naphthenic acids in the past, the culprit was recognized at once. The first condensate from the vapor stream was formed in the top condenser and contained a high concentration of naphthenic acids in the oil. Hence, the severe localized corrosion. As the condensate dripped off the tubes and ran down the baffles it corroded the grooves and where a constant drip occurred on the shell a groove was formed there as well. Because there were no longitudinal baffles in the tube bundle, some of the hot vapor bypassed around the outside, thus keeping the shell and the condensate hot. Until condensate formed there was no corrosion. As soon as the temperature dropped 10 to 15 degrees F the corrosion dropped to a very low rate. Brass tubes were not affected because their wall temperature was well below the corrosive range. Repairs were made by installing a vapor stop in the top of the bundle to prevent bypassing and installing Type 316 Cr Ni Mo shrouds on the lower part of the bundle to prevent drips on the shell. The shrouds were placed so as to drop the condensate directly on the tube bundle in the lower condenser where it would be quickly cooled and diluted by additional oil condensate. At the last inspection after three years operation no further corrosion was noted. It is interesting to note that the indicated corrosion rate was 0.020-inch/1000 hours. Because not all the crudes processed in this unit contain naphthenic acids, the actual corrosion rate, therefore, may have been two to three times higher than the observed rate while the corrosion was taking place.

Corrosion in Gasoline Tanks

The type of corrosion that causes considerable trouble is the slow, seemingly harmless variety which is accompanied by large scale accumulations. This is particularly true of large gasoline storage tanks. The corrosion rates are low compared to rates encountered in process equipment but still are sufficient to cause major repairs after 10 years or more of service. Shells of these tanks are difficult to inspect because of the large area involved and because they are covered with a thick layer of scale. About 1942 it was discovered that some tanks were at or close to the minimum allowable thickness for full filling height. Since that time an extensive program of gaging the shell and roof of all the standard tanks has produced considerable data. One of the first things discovered was that early tank designs pro-

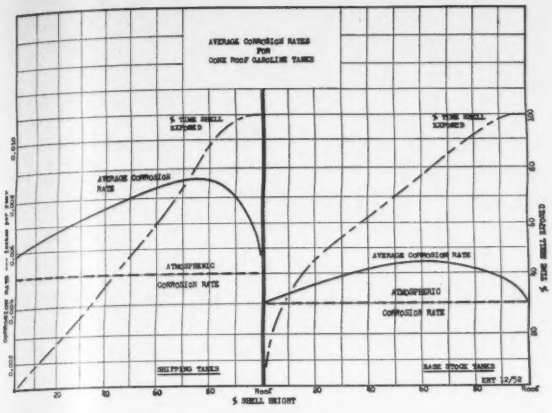

Figure 2

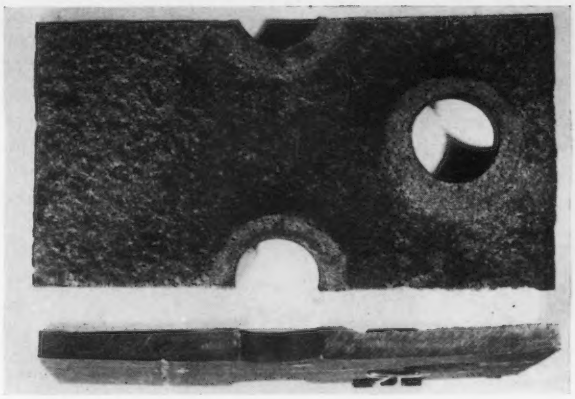

Figure 3

vided a very low corrosion allowance in the area of the highest corrosion. This also is true in many cases with the present day standard American Petroleum Institute tank design.

It is impossible for the inspector to arrive at a true corrosion rate for tanks because there are so many variables involved. The temperature and physical properties of the stock; the working levels and the rate of filling and emptying and the atmospheric conditions all have an effect. In addition, the service may be switched among stocks over a period of years. If the corrosion rate for the various courses of tanks in similar service are grouped and plotted as a function of the shell height, the data is inconclusive. However, if the rates for each course are averaged and then plotted the variation in corrosion as a function of the shell height easily can be seen. This is illustrated in Figure 2 which shows the average corrosion rates for cone roof tanks in gasoline base stock and shipping service. The size of these tanks varies from 90 x 30 feet to 150 x 48 feet. Note that the corrosion rate for the shipping tanks is about twice that of base stock tanks. There is some difference in the atmospheric corrosion rate between the two groups because of their distance from the ocean. The shipping tanks are located on a hill about a quarter mile from the beach while the others are behind the hill and are about a mile from the beach. The most important difference is in their method of working as can be seen from the curves showing the time the shell is exposed. The shipping tanks are usually filled to a high level, held for several days, pumped out and then filled again. This happens about two to four times a month. The base stock tanks on the other hand usually work at lower levels or stand for long periods of time either empty or full. In both cases the shell corrosion rate is substantially above the atmospheric corrosion rate. The highest rate occurs where the shell is exposed about 75 percent of the time. This is at 60 percent of the shell height for the base stock tanks and 80 percent of the shell height for the shipping tanks. From an examination of the scale, corrosion curves and other factors, it appears that corrosion takes place almost constantly under the liquid level. The rate will depend on the quantity of water and oxygen absorbed into the stock. Corrosion on the roof and exposed portions of the shell which proceed at the atmospheric rate will occur only while the shell is wetted with condensed moisture.

Figure 3 illustrates a typical corroded riveted joint from a gasoline tank. The greatest loss in thickness occurs adjacent to the rivets but under the rivet heads the plate remains the original thickness. Additional thickness next to the rivet holes adds to the net section and materially increases the joint strength in tension. In some recent tests a joint which originally had an efficiency of 65 percent failed with an indicated efficiency of 85 percent after the plate had lost 0.15-inch in thickness. Because there is no way of predicting the actual efficiency of a corroded joint, the original joint efficiency always should be used to calculate the strength of the joint in service. Notice that the joint has been poorly caulked and a groove has been formed in the plate. The groove is away from the weakest part of the joint but it still can be a factor because of the notch effect. Whenever this condition is found the strength of the joint should be calculated for the net section of the plate at the bottom of the groove using a joint efficiency of 100 percent in addition to the regular joint calculation. The lesser of the two should then be used to calculate the safe filling height of the tank.

Acknowledgment

The author thanks E. J. Arveson, Assistant Chief Engineer of the El Segundo Refinery for his assistance in preparing this article.

DISCUSSION

Remarks by Arthur R. Houser, Wood River, Ill.: It appears that more interest should be shown in the joint efficiency of riveted storage vessels. The author mentioned that joint efficiency of riveted joints actually increases as the vessel corrodes. This indicates that studies and tests to determine the correct assigned value might prove economical. The actual joint efficiency of a lap joint where shear on the rivets was originally the determining factor actually causes an increase of the joint efficiency as the thick-

ness of the shell decreases. Especially where oversize rivet heads are used to combat corrosion, the portion of the plate under the rivet heads is usually not attacked by corrosion, so bearing and shear stresses in the joints would not be increased as fast by corrosion as the stresses in the plate away from the joints. Tests to failure of sections of corroded riveted joints at least would be interesting and might provide a more definite basis for calculating or assigning joint efficiencies to corroded riveted joints.

Reply by E. H. Tandy:

Tests indicate that a real increase in joint efficiency is not found until there has been a plate surface loss of 0.10-inch or more. Because the joints cannot be gaged accurately, I would not recommend using an increased joint efficiency factor except in the case where shear governs. In this case, the joint strength can be calculated using the gaged plate thickness and the original joint efficiency in tension since the shear strength remains the same. Some joints may be lap welded and the rivets seal welded to gain a maximum joint efficiency of 75 percent. Each joint, however, must be evaluated on the conditions found at that particular spot. Not all joints in the same tank will corrode alike and there may be other factors such as undercutting from caulking which would affect the strength.

Remarks by F. W. Prange, Phillips Petroleum Co., Bartlesville, Okla.:

As one reads Mr. Tandy's paper, it would be profitable to compare it with the inspection methods recommended by the API-ASME code. Mr. Tandy's remarks illustrate the code provisions very nicely.

Reply by E. H. Tandy:

Mr. Prange's point about the API-ASME Code inspection methods is well put. The code of course, is limited to pressure vessels alone. However, the API Recommended Practices for Refinery Inspections is an excellent guide for all refinery equipment. I would like to point out that simply inspecting the equipment and reporting the findings is not enough. To be of real service to its company, the inspection group must have ample records of all equipment so inspection results can be analyzed and reported intelligently. Careful analysis of past records and present conditions will enable the inspector to predict future difficulties and recommend mitigative measures, thereby preventing costly equipment replacement.

Cathodic Protection in Florida Power and Light Company's Generating Plants*

By JOSEPH B. PRIME, JR.

THIS PAPER deals with stations that use salt water as a cooling medium and structures that are directly in contact with this medium. These structures consist of the intake structures (trash racks, traveling screens, and fine screens) and surface condensers. The screen structures are 8 feet wide by 26 feet long. These screens are almost entirely submerged except for short periods for cleaning purposes. The traveling screens are rotated every four hours for cleaning purposes and are stopped so that different sections are left in the water in rotation. Because these structures are in contact with low resistance water, corrosion is very rapid and cost maintenance and replacement very high.

In 1948, several tests were started at Florida Power and Light Company's Miami Plant on the north bank of the Miami River about half a mile west of where the river enters Biscayne Bay. The water at this location varies with the seasons of the year, from fresh through brackish to sea water. It also contains large amounts of organic material from the Everglades and is extremely corrosive. Protection tests were started by using four anode clusters of scrap boiler tubes, hung vertically in the plan center of the intake wells, close to the structures to be protected. These anode clusters were connected in a forced drainage system through a 50 amp/18 volt* rectifier to the structures. One rectifier was used for two trash racks, two traveling screens and two fine screens. This circuit lowered (made negative) the potentials of these intake structures to close earth ($CuSO_4$ half-cell) to an average of —.96 volts.

Further tests were made during this period for information pertaining to the effect of the protection system on reinforcing steel. After these tests were completed, it was decided that for most effective operation of the protection system it would be desirable to isolate all the intake structures from other structures (reinforcing steel, etc.). Also, higher current densities could be applied without danger of hydrogen evolution around reinforcing rods causing cracked cement. Along with these tests, it was noted that the tidal areas of the structures were receiving approximately 50 percent protection. This was determined through visual observation over a period of several years.

Originally, these intake structures were galvanized, but at the time protection was applied the galvanizing had disappeared and the exposed iron was badly deteriorated. This condition was noted on both the frames and screens.

A few months after protection was applied to these intake structures, all signs of active corrosion had disappeared and a thin calcareous film had formed over them. This film was controlled on the screens by regulating the current flow to them. No trouble was experienced with a heavy "build up" to the extent it impeded water flow through the screens.

Although the system was doing a very excellent job it was noted that the iron anodes were the "weak links" in the system, a result of the high sacrificial rate of iron which made the maintenance cost on the system high.

★ A paper presented before Jacksonville Section, National Association of Corrosion Engineers, at Jacksonville, Fla. on May 15, 1953 which includes also material presented by the author at the Tenth Annual Conference, National Association of Corrosion Engineers, Kansas City, Mo., March 15-19, 1954.

* All current readings in this paper are negative and DC.

JOSEPH B. PRIME, JR.—As Protection Engineer for Florida Power and Light Company, he handles all corrosion mitigation work on the company's system. He has a BS in electrical engineering from University of Miami and is an Air Corps veteran of World War II. He is a member of American Institute of Electrical Engineers and NACE.

Abstract

Cathodic protection of intake structures and seawater cooled condensers at plants of Florida Power and Light Company has proved practical and economical during the past 5 years. Systems involving both rectifier current and galvanic current from sacrificial anodes are being employed. Experience at the plants indicates that a combination of copper screen and black iron for moving racks gives better service under cathodic protection. Inspection of protected structures shows substantial and satisfactory protection is being obtained in the tidal zone. Insulation of intake structures from reinforcing steel in concrete is recommended to permit application of greater densities without chance of cracking concrete through accelerated rusting of reinforcement. Experiments with condensers prove insulation of condenser tubes from water boxes is desirable. Tests with three condensers showed the value of insulation and cathodic protection. Author recommends attention to cathodic protection needs in designing structures.

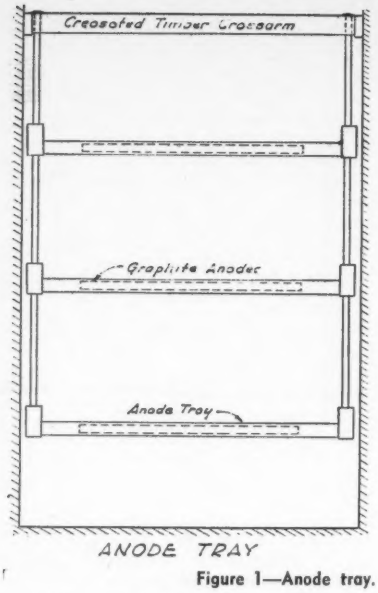

Figure 1—Anode tray.

After much time was spent on design and testing for a good workable anode tray, a tray to hold 6 x 82-inch NA graphite anodes (as shown in Figure 1) was approved for all plants. The number of anodes in each tray is determined by the depth of the wells and the underwater area of the structures. In Figure 1A, location of anode trays in respect to structures is shown. The holders for the anodes are made from 8-inch class 150 Transite pipe, split longitudinally with 1¼-inch galvanized pipe used for frames. To protect the galvanized pipe, controlled drainage current is applied to them. Along with the anode trays, a test panel was designed so that all circuits could be controlled from this panel (Figure 1B shows a typical panel).

In 1949 another 50 ampere rectifier was connected in parallel with the first to give a greater applied current to the system. This was needed because of the changing resistance of the water and exposed areas of the intake structures due to tidal change. The water resistance changes by seasons of the year. Sometimes in the rainy season (Summer), the rains are greater in the Everglades section than other times. This changes the resistance of the Miami River very appreciably.

In 1950 two new traveling screens and two rebuilt trash gates were placed in operation in two intake wells parallel with the first two discussed above. The traveling screens were completely galvanized according to company specifications. After installation, these screens were placed under cathodic protection. These structures were kept to an average potential of —1.12 volts to close earth ($CuSO_4$ half-cell). At this time, it was thought that galvanizing was the best coating for the structures. About a year later, this theory was proved wrong. The traveling screens were in excellent condition as a whole, but the screen cloth was in a serious state of deterioration. Testing on these screens indicated that the corrosion was the result of several reactions. Very high alkaline conditions on the surface of the structures (pH12 to 14) caused by the cathodic protection, resulted in a uni-

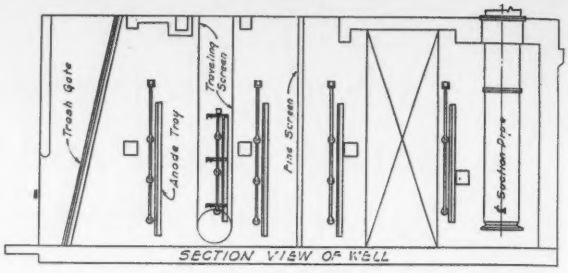

Figure 1A—Installation of anodes at intake.

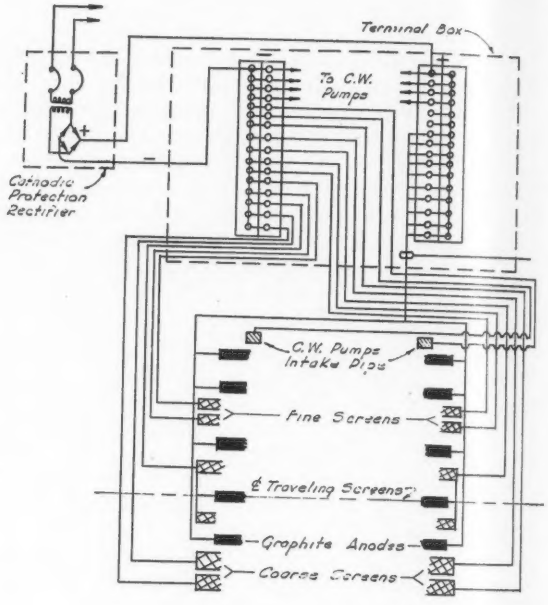

Figure 1B—Test panel.

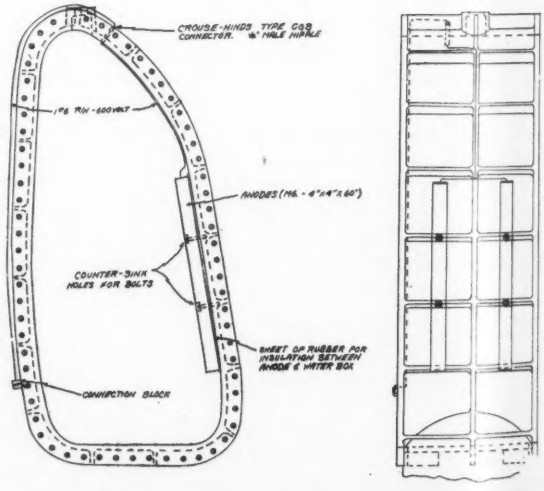
CROUSE-HINDS TYPE CGB CONNECTOR. ¾" MALE NIPPLE
1"Ø THN-600VOLT
ANODES (MG.-6"x4"x60")
COUNTER-SINK HOLES FOR BOLTS
SHEET OF RUBBER FOR INSULATION BETWEEN ANODE & WATER BOX
CONNECTION BLOCK

Figure 2—Typical anode installation in condenser water box.

form corrosion of the zinc. Also, due to resistance developed between the wires and between wires and frames there was insufficient protection on the screen cloth itself.

Protection was applied on No. 6 surface condenser at Miami in 1949. To this time corrosion had caused great areas on the water boxes of this condenser to become graphitized and tubes were being replaced at a high rate. The initial installation consisted of four magnesium anodes (4 x 4 x 60-inch) placed in either water box and insulated from the boxes at place of attachment. Leads were brought from the anodes through the top of the condenser to a terminal block on the outside (Figure 2 shows typical installation). The open circuit voltage averaged —0.83 and short circuit current averaged 10.3 between anodes and water boxes. Water velocity through these condensers is approximately 6.4 ft/sec. The tube alloy is aluminum brass and the tube sheets are Muntz metal.

Such good results were obtained on No. 6 condenser (service records indicate that a 30 percent increase in the life of the tubes was being experienced after application of protection) that the protection was applied in 1951 to three other condensers at this plant. The same plan was used with the only factor being the number of anodes to condensers. This was due to the difference in areas of the condensers and with a criterion of approximately 2 milliamperes per square foot of exposed metal.

Tests of No. 6 condenser have been underway long enough to indicate what protection has accomplished. No noticeable change in reduction of tube failures were noted at the end of the first year of protection. All exposed graphite areas were dissipated, leaving clean protected metal. In the second and third years, reduction of tube failures averaged 30 percent.

Riviera Plant Is Protected

Riviera plant's intake structures were placed under protection in 1948. This plant is located on the west shore of Lake Worth, about three miles north of West Palm Beach. The water is considered clear sea water with substantial marine life. The intake structures were installed and placed in operation in 1946. The intake structures were galvanized with the traveling screen having copper screen cloth. Between 1946 and 1948, when protection was applied, most of the galvanizing had been sacrificed and corrosion was very evident on the structures. After a few months of applied protection, all rust had been removed from the structures and a thin, even calcareous film had been deposited.

After approximately five years of protection, all structures are in excellent condition and all corrosion had been stopped. The output of the forced drainage system has been on an average of 46 amp/2.5 volts, giving average close $CuSO_4$ potentials to structures of —1.08 volts.

An additional unit is being built at Riviera and it is planned to place the new and old surface condensers under protection at the same time. The new condenser will have insulated water boxes (i.e., electrically insulated from shell and tube sheets) while the old condenser will be placed under protection with shorted water boxes. As in other plants, magnesium anodes will be used in the water boxes for galvanic anodes.

Miami Beach System Installed

At this same time (1949), cathodic protection was applied to the intake structures at Miami Beach Plant. This plant is located on the south shore of Terminal Island on MacArthur Causeway. Water for cooling is taken from the ships' channel in front of the plant. Structures were galvanized and copper screen was used on the traveling screen. At time of applying protection, all galvanizing had disappeared and a heavy rust scale had formed. About six months after applying cathodic protection, most of the heavy rust had been replaced by a calcareous film. The copper screen cloth had changed from a brown copper oxide to a bright copper color, with some evidence of a calcareous build up. At this time, five years after applied protection, all structures are in excellent condition. These structures have been protected with an average of 45 amp/3 volts applied at the rectifier giving an average $CuSO_4$ half-cell potentials on the structures of —1.12.

Sarasota Steam Plant Work

Probably the most corrosive steam plant site in the system is the one at Sarasota. The intake wells for this plant are located on the north bank of an inlet, about 500 feet from Sarasota Bay. The water is clear, highly corrosive and supports substantial amounts of barnacles and other marine life. The intake structures at this plant consist of two traveling screens, two trash racks and two fine screens. The first screen (east) is of black iron with copper screen cloth. The second screen (west) is a galvanized structure with galvanized screen cloth. The second screen was installed at the time of an addition to the plant in 1951. The first screen was installed in 1946, at the time of plant construction and was placed under protection in 1948. About a month after protection was applied to the first traveling screen and other structures, most of the rust scale and barnacles had disappeared, leaving a calcium-magnesium film, about 1/16-inch thick, brittle and easily chipped off in large flakes. At present, no further corrosion is evident on these structures and barnacle growth has been retarded but not eliminated.

The second screen and structures, which have been under protection since the time of installation, are in excellent condition with the exception of the screen cloth on the traveling screen. The reaction experienced on the Miami Plant galvanized screen cloth was repeated on this traveling screen.

These structures in the two intake wells are requiring an average of 50 amp/3.25 volts each well to give average potential readings to $CuSO_4$ half-cell of —1.18 volts. Structures in first well are not isolated from plant ground while second well structures are isolated.

Because of very corrosive soil conditions, it was found necessary to place all of the underground structures at Sarasota Plant under cathodic protection.

TABLE I

Condenser	Reading
No. 1	Intake-Outlet end V_{oc} = — .235 volts and I_{sc} = — 1.81 amp
	Reversing end V_{oc} = — .098 volts and I_{sc} = — .60 amp
No. 2	Intake-Outlet end V_{oc} = — .19 volts and I_{sc} = — 1.7 amp
	Reversing end V_{oc} = — .127 volts and I_{sc} = — 1.63 amp
No. 3	Intake-Outlet end V_{oc} = — .48 volts and I_{sc} = —12.0 amp
	Reversing end V_{oc} = — .15 volts and I_{sc} = — 9.5 amp

This was accomplished by using a rectifier and ground bed consisting of ten graphite anodes. This system was put in operation in 1949 with an average output of the rectifier of 37 amp/8.8 volts, sufficient to "swing" the structures negative on an average of .34 volts to a $CuSO_4$ cell. After two years, structures uncovered for construction purposes did not show further signs of corrosion.

The two surface condensers at this plant are under cathodic protection from magnesium anodes. The original condenser was not placed under protection until the first part of 1952. At time of installation of protection, large areas of water boxes were graphitized and some attack was under way on the tube ends. At last inspection of this condenser, about a year after the system was installed, the graphite was being lifted from the water boxes and action on the tube ends had ceased. This condenser has the water boxes shorted to the shell.

The second condenser, installed in the latter part of 1950, has insulated water boxes and has been under protection since time of installation. No visual corrosion has taken place either on the water boxes or tubes.

Much Work Done at Cutler

The plant that has probably received most of the testing and experimental work is located at Cutler, 15 miles south of Miami on a slip extending inland from Biscayne Bay. The water is clear, with slight marine growth.

The original installation at this plant contained three sets of intake structures, with foundations for all structures specifically designed for cathodic protection. Great care was taken to insure that all structures were isolated from the reinforcing steel. All structures were galvanized and galvanized screen cloth was used on traveling screens. For the three sets of intake structures an average of 90 amp/6 volts drain current was needed to hold the structures to an average —1.24 volts to close $CuSO_4$ half-cell. The potential of —1.24 was kept on these structures for protection of the galvanizing but a year after protection had been applied on the intake structures, the traveling screens' galvanized wire began to show serious deterioration as had those at the Miami and Sarasota plants. The same reasons for this effect were ascribed to the reaction on the Miami Plant's wire baskets. One traveling screen's wire cloth has been changed to copper and the others will be changed as soon as conditions warrant. Testing of steel wire cloth at this plant in the near future is planned.

Current Flow Theories Tested

Up to this time, theories of galvanic action between water boxes and tubes were that definite current flows on a condenser which reversed as the condenser's water boxes graphitized. When a condenser is new, current flows from the water boxes to the tubes and tube sheets. As areas of graphitization form on the inside of the water boxes due to current flow, the current will reverse and flow from the tube and tube sheets to water boxes. Cutler Plant was picked as the proving ground for the above theories because original installation required three surface condensers. At time of installation all three condensers were constructed so that water boxes were insulated (electrically) from the shell (tubes and tube sheets). It was decided to operate No. 1 condenser short circuited to see if and when the current would reverse. No. 2 condenser was operated on open circuit and No. 3 condenser was operated open circuit with cathodic protection applied.

Before the tests were started on May 19, 1949 current and voltage measurements were taken shown in Table 1. (All measurements are head-to-shell with recording voltmeter):

On October 17, 1950 it was found that the zero point in potential and current polarity had been reached on No. 1 condenser. The inside of the water boxes had a thin, even graphite scale with intermediate pits from ⅛ to ¼-inch deep about ½-inch in width. No. 2 condenser still had a negative potential and current flow. The inside of the water boxes showed some signs of local cell action. In comparison with No. 1 condenser, No. 2 condenser was in excellent condition. No. 3 condenser had no signs of corrosion either on the water boxes or tubes.

On July 10, 1951 the shorts were removed from No. 1 condenser because it was felt that to carry the test further, would cause permanent injury to the tubes. All of the condensers are now under protection. Also, testing is still in process on condensers to determine if some current shouldn't be shunted to the tubes and tube sheets. As of this date, not enough data has been obtained to answer this question.

Results Surveyed

In conclusion, it might be well to bring out several points in conjunction with cathodic protection. It is found that a 50 percent reduction in corrosion is obtained on the structures over the tidal area, which means, that a good paint application will have to take over above the water line where cathodic protection leaves off. Condensers can be very effectively and economically protected with galvanic anodes. The best combination for intake structure, if cathodic protection is applied, would be copper screen cloth with black iron frames covered with normal shop coating. Cathodic protection will cause blistering of paint coatings, but enough film is left intact to effect a reduction in surface area and, thereby, a current reduction. Greater economy and more effective results can be had with cathodic protection for new installations if certain protection concepts can be incorporated in the original design. In each case, where cathodic protection has been applied to the plants, corrosion has been stopped or mitigated to a point where a substantial maintenance reduction has been effected. In all cases, the plant superintendent and operators are very well satisfied with the protection provided and have found the method economically sound.

Final Report

Effect of Exposure to Soils on The Properties of Asbestos-Cement Pipe*

By MELVIN ROMANOFF and IRVING A. DENISON*

Contents

1. Introduction
2. Properties of the Soils at the Test Sites
3. Description of the Materials
4. Test Procedures
   4. General Plan and Methods
   4. Surface Condition
   4.3 Hydrostatic Bursting Pressure
   4.4 Crushing Strength
   4.5 Water Absorption and Apparent Specific Gravity
5. Mechanical and Physical Properties of the Exposed and Unexposed Samples
6. Summary
7. References

Abstract

The final results of a study of two varieties of asbestos-cement pipe after exposure to a wide variety of soil conditions for a maximum of 13 years are reported. The data presented in a previous paper indicated that certain mechanical and physical properties of the material are affected by exposure to the soils. The samples of asbestos-cement pipe gained appreciably in strength during the early periods of exposure, thus indicating that the curing process continues for several years during exposure underground. The present paper summarizes the previously published data and reports the effect of the same soils on the pipe samples after completion of the curing period. The effects of exposure to the soils on the properties of asbestos-cement pipe are indicated by measurements of hydrostatic bursting pressure, crushing strength, water absorption, apparent specific gravity and condition of the surface of the specimens removed.

1. Introduction

AS PART of its comprehensive field investigations of materials for underground construction, including ferrous and nonferrous metals[1,2,3] the National Bureau of Standards exposed two varieties of asbestos-cement pipe to the soils at 15 test sites exhibiting a wide range of soil conditions. The exposures were started in 1937 and 1939.

The asbestos-cement pipe used was a mixture of approximately 80 percent by weight of portland cement and 20 percent asbestos fibers. it was formed by a continuous process on a revolving steel mandrel, with the material being built up and compacted under heavy pressure; the pipe was then subjected to a curing operation. Nearly all of the asbestos-cement pipe made in this country is produced by this method.

In a previous report[4] data were presented which indicated that certain mechanical properties of asbestos-cement pipe are affected by exposure to the soils. During the early periods of exposure, the samples of asbestos-cement pipe gained appreciably in strength, thus indicating that the curing process may continue for a number of years. The strength of samples exposed to certain soils tended to decrease somewhat after their maximum strength had developed, but no definite trends were indicated by the incomplete data. With the termination of the field tests in 1952, specimens exposed for longer periods were made available, thereby providing additional data for evaluation of the behavior of asbestos-cement pipe after completion of the curing process.

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2. Properties of the Soils at the Test Sites

The location of the test sites, the identification of the soil types and the chemical and physical properties of the soils are given in Table 1. The properties of the soils show that the test sites are representative of a wide range of soil conditions. For example, the electrical resistivities of the soils range from 62 ohm/cm, indicating a high concentration of soluble salts, to 17,800 ohm/cm, indicating the practical absence of such salts. Other marked differences are indicated by the hydrogen-ion concentration of the soils which ranges from pH 2.6 to 9.4 and by the composition of the water-soluble material in the soils, as for example, the preponderance of chloride in soil 64 and of sulfate in soil 60.

At several of the test sites the soils are highly oxidized to considerable depths, whereas in others the permanent water table is close to the surface. The retentiveness of the soils for water is indicated by the values for moisture equivalent which is the quantity of water retained by a previously saturated soil against a centrifugal force of 1000 times gravity. The apparent specific gravity, which is the weight of a unit volume of undisturbed soil, is an index of the relative compactness or porosity of inorganic soils because the true specific gravity of the mineral particles in soils varies only within narrow limits.

The soils were classified according to the type of environment, as indicated in Table 1. The soils, excepting cinders, are placed in two main divisions depending on whether they are inorganic or organic. The inorganic soils are then divided into two groups according to their oxidizing or reducing nature. All

of the organic soils were reducing and acid in reaction.

3. Description of the Materials

The two varieties of asbestos-cement pipe included in the field tests were designed to withstand a pressure of 150 lb/in.² (class 150 pipe). The 6-inch specimens, buried in 1937, were fabricated from a thin slurry of portland cement and properly prepared asbestos fibers, which was picked up as a continuous sheet from the container vat on the wire screen surface of a partly immersed, rotating cylinder mold. This sheet, ranging in thickness from 0.010 to 0.020 inch, had a width equal to the full length of the pipe sections being manufactured. The sheet was transferred from the mold to an endless felt belt, carried forward over a vacuum chamber to remove excess water and again transferred to a mandrel on which the pipe was formed continuously, until the required wall thickness was attained, under heavy compressive force exerted by a system of pressure rollers. The pressure applied during the process was not sufficient to cause any change in the chemical properties or structure of the portland cement.

The 4-inch specimens, buried in 1939, were fabricated by essentially the same process, the only significant difference being in the way the slurry was transferred from the felt to the mandrel. There were six felts, each about 10 inches wide, held in contact with the mandrel by compressing rollers. The mandrel was spiraled helically forward through the machine at the rate of about 1 inch per revolution and the pipe was built up during this process.

When the required thickness was reached by either process, the seal between the mandrel and the pipe was released by the introduction of air between the mandrel surface and the pipe. This operation, necessarily carried out without the high pressures used while the pipe was being formed, added a small thickness of relatively uncompacted stock to the outside surface. This stock was in excess of the designed wall thickness and is known as the calendar layer. It was noted prior to exposing the specimens at the test sites that the calendar layer was slightly softer than the main body of the pipe.

After removal from the mandrel, the 6-inch pipe was cured by a high-pressure steam process in which heat and pressure were applied to the pipe in a moisture-saturated atmosphere. Silica flour was added to the slurry during the manufacture of these pipes to facilitate the chemical reactions resulting from steam curing. The 4-inch pipes were cured by submersion in water 2 to 3 weeks, after which they were trimmed and machined.

4. Test Procedures

4.1 *General Plan and Methods*

In 1937, 10 samples of 6-inch diameter pipe were installed at each of 15 test sites to provide for removal of two samples after each of five periods of exposure. The specimens were 12 inches in length and had an average wall thickness of 0.72 ± 0.05 inch. The ends of the pipe were not sealed and since it was the intent to limit exposure to the soil to the exterior surface, the interior surface and the ends were coated with a resinous varnish. Samples were removed from each site in 1939, 1941, 1946, 1948 and 1950.

On the occasion of the removals in 1939, samples of pipe 4 inches in diameter were buried at the same

TABLE 1—Properties of the Soils at the Test Sites

Test sites								Total acidity[2] (milligram equivalent per 100 g of soil)	Composition of water extract (milligram equivalent per 100 g of soil)						
Environment and soil type	Soil	Location	Aeration[1]	Moisture equivalent	Apparent specific gravity	Resistivity at 60° F (15.6° C)	pH		Na+K as Na	Ca	Mg	CO_3	HCO_3	Cl	SO_4
INORGANIC OXIDIZING SOILS															
				Percent		*§Ohm-cm*									
Cecil clay loam	53	Atlanta, Ga.	G	33.7	1.60	17,800	4.8	5.1	....	...	...	...	...	...	...
Hagerstown loam	55	Loch Raven, Md.	G	32.0	1.49	5,210	5.8	10.9	...	...	...	...	...	...	...
Susquehanna clay	62	Meridian, Miss.	F	34.6	1.79	6,920	4.5	12.0	...	...	...	...	...	...	...
Chino silt loam	65	Wilmington, Calif.	G	26.4	1.41	148	8.0	A	7.56	12.40	2.20	0.00	1.30	6.05	16.90
Mohave fine gravelly loam	66	Phoenix, Ariz.	F	16.5	1.79	232	8.0	A	6.55	0.51	0.18	.00	0.73	2.77	2.97
INORGANIC REDUCING SOILS															
Acadia clay	51	Spindletop, Tex.	P	47.1	2.07	190	6.2	13.2	10.27	15.55	5.03	0.00	0.56	5.75	22.00
Sharkey clay	61	New Orleans, La.	P	30.8	1.78	934	6.8	4.9	0.73	0.68	0.33	.00	.71	0.10	0.91
Docas clay	64	Cholame, Calif.	F	41.1	1.88	62	7.5	A	28.10	2.29	.76	.00	.89	28.80	.26
Lake Charles clay	56	El Vista, Tex.	VP	28.7	2.03	406	7.1	5.1	3.12	0.69	.47	.00	.80	1.59	3.04
Merced silt loam	70	Buttonwillow, Calif.	F	24.7	1.69	278	9.4	A	8.38	.38	.22	.02	1.87	1.12	5.57
ORGANIC REDUCING SOILS															
Carlisle muck	59	Kalamazoo, Mich.	VP	43.6	...	1,660	5.6	12.6	1.03	3.08	2.70	0.00	0.00	3.47	1.04
Muck	58	New Orleans, La.	P	57.8	1.43	712	4.8	15.0	2.03	2.23	1.29	.00	.00	0.47	2.54
Rifle peat	60	Plymouth, Ohio	P	43.4	1.28	218	2.6	297.4	2.91	10.95	2.86	.00	.00	.00	56.70
Tidal marsh	63	Charleston, S. C.	VP	46.7	1.47	84	6.9	14.6	33.60	6.85	4.00	.00	.00	12.70	36.60
CINDERS															
Cinders	67	Milwaukee, Wis.	VP	...	...	455	7.6	A	0.77	3.03	0.53	.00	.55	0.08	2.89

[1] G, good; F, fair; P, poor; VP, very poor.
[2] A, alkaline reaction.

sites. These specimens were 15 inches in length and had an average wall thickness of 0.64 ± 0.09 inch. The specimens were tapered 2½ inches from each end and closures were placed at the junction of the tapered and untapered portions to confine the action of the soil to the external surface. Two samples of this material were removed from each site after exposures of 2, 7, 9, 11 and 13 years. Because it was necessary to discontinue the tests at one site (soil 51) in 1946, six samples of the 6-inch pipe and 10 samples of the 4-inch pipe were removed from this location at that time.

The specimens as periodically removed were returned to the laboratory for examination of their surfaces and for the determination of their respective hydrostatic bursting strengths, crushing strengths, water absorption and apparent specific gravity. Five representative samples from each of the 4-inch and 6-inch "as manufactured" pipe, which were stored at the Bureau, were subjected to the same tests. In addition, a section from each length of pipe from which the 4-inch diameter specimens were cut was subjected to these tests by the manufacturer and the Pittsburgh Testing Laboratory in accordance with the same procedures employed at the Bureau. The determinations made on the unexposed samples were used as reference data in determining the effect of the various soils and periods of exposure on the pipe materials.

In order to stimulate service conditions with respect to moisture, the 6-inch specimens were immersed in water for 48 hours before making the bursting and crushing tests. However, the 4-inch specimens were tested in the air-dry condition because the reference samples had been tested in this condition. In this connection, it may be noted that saturation with water reduces the strength of asbestos-cement pipe from 10 to 20 percent.[5]

4.2 *Surface Condition*

The depth of softening of the surface was estimated in a semiquantitative manner by scratching or scraping the external surface, allowing for the original condition of the outermost or calendar layers. Based on these observations, the condition of the surface was classified according to the following categories:

A, hardening of the calendar layers;
B, surface unchanged;
C, softening to a maximum depth of 0.06 inch;
D, softening to a maximum depth of 0.15 inch.

During the latter part of the investigation, quantitative measurements of the depth of affected surface layers of the exposed specimens were made by a method developed by the Johns-Manville Research Center.[6] Staves were cut from the specimens, 4 inches along the length of the pipe and 2 inches in width. A stave of an exposed specimen was mounted in a precision lathe, and the surface layers, which had been softened by contact with the soil, were removed by grinding under carefully controlled conditions. The grinding operation was continued until the measured hardness was equal to that of unexposed reference asbestos-cement pipe. The thickness of the softened layer was then taken as the difference in thickness between the original and residual wall, as measured with a micrometer, or by recording the movement of the graduated compound cross feed of the lathe. In measuring the hardness of the specimen, a cut was made with a tool so designed that the width of the cut varied with the applied load and hardness according to the formula.

$$\text{Hardness number} = \frac{\text{Applied load (g)} \times 1000}{\text{Width of cut (mm)} \times 0.1}.$$

Preliminary evaluation of softening of the 6-inch specimens developed during nine years of exposure was made on a single stave cut from each specimen. However, the determinations of softening of the 4-inch and 6-inch specimens exposed for 11 and 13 years were made on four staves cut at random from each sample.

4.3 *Hydrostatic Bursting Pressure*

The 4-inch specimens were prepared for the hydrostatic bursting tests by removing the closures and the tapered ends, the length of the specimens being thereby reduced to 11 inches. The 6-inch specimens required no alteration in their shape or size. The tests were made on only one specimen for each exposure period from each of the test sites.

The apparatus for determining the bursting strength was provided with internally fitting rubber gasketed heads to close the ends of the pipe and so designed that the pipe was not subjected to end compression during the test. A vent arrangement for expelling air entrapped in the pipe during test was provided at one of the heads. The opposite head was equipped with a water and pressure inlet, the pressure being provided from a high-pressure hand pump. Backing up of the pressure into the inlet line was prevented by use of suitable check valves.

After filling the pipe with water, the entrapped air was allowed to escape and the pressure was increased at the rate of approximately 10 lb/in.^{2}/sec until the pipe failed. The pressure gauge employed was calibrated before and after the tests for each exposure period and the bursting pressures, shown in Tables 2 through 5, are the values obtained after applying the correction factor. The corresponding maximum tensile stress values were calculated from the respective bursting pressures by use of the formula shown below.

The minimum, or average, wall thickness along the fracture as well as the location and character of failure of each specimen were noted. Many specimens failed initially by splitting out of a section of the pipe at one end, following which a crack propagated from a point on this fracture along the entire length of the specimen. The others failed by cracking in one or two places simultaneously along the entire length of the specimen.

Direct comparison between the bursting pressures of the exposed and unexposed specimens is not valid unless the variations of wall thickness and diameter are taken into account. This was accomplished by

TABLE 2. Mechanical and Physical Properties of 4-Inch Asbestos-Cement Pipe After Exposure to Soils[1,2]

SOIL No.	SOIL Type	Exposure	BURSTING STRENGTH[3] Identification of pipe from which specimen was cut	Bursting pressure	Tensile strength	Difference from unexposed	CRUSHING STRENGTH[4] Identification of pipe from which specimen was cut	Crushing load	MODULUS of RUPTURE	Difference from unexposed	Water absorption[5]	Difference from unexposed	Apparent specific gravity[5]	Difference from unexposed	Depth of Softening[6]
		Years		lb/in.^{2}	lb/in^2	lb/in^2		lb/linear ft	lb/in^2	lb/in^2	Percent	Percent			In.
51	Acadia clay	7.0	P	1,300	5,210	750	P	13,060	12,030	2,470	9.2	—5.4	1.94	0.07	C
			I	1,075	4,360	90	T	13,090	10,510	2,370	11.8	—3.7	1.86	.06	C
			Q	775	3,550	190	U	10,930	11,590	2,640	11.1	—4.0	1.88	.06	C
			O	825	3,600	310	V	12,470	10,620	3,160	10.3	—5.4	1.90	.11	C
			L	1,075	4,290	90	K	12,740	11,010	1,300	10.6	—5.4	1.90	.09	C
53	Cecil clay loam	1.9	C	1,050	4,070	880	T	10,030	8,350	210	14.4	—1.2	1.76	—.05	B
		6.8	S	1,150	5,000	740	E	11,440	9,720	960	9.2	—5.4	1.94	.10	B
		9.1	V	1,245	4,890	770	S	10,060	10,890	2,420	11.2	—2.8	1.89	.05	B
		10.6	B	1,170	4,600	60	H	12,830	11,170	2,470	11.8	—3.3	1.88	.05	.018
		12.8	M	1,100	4,060	—40	D	9,540	9,210	1,310	15.7	—1.6	1.79	.03	.043
55	Hagerstown loam	2.0	S	1,000	4,120	—140	G	12,930	11,190	1,670	11.4	—2.1	1.78	—.07	B
		7.1	O	1,000	4,590	1,300	J	13,240	11,510	1,190	10.3	—6.0	1.90	.12	B
		9.1	C	885	3,680	490	F	16,080	11,030	1,430	12.1	—3.4	1.86	.05	B
		10.8	H	1,480	5,520	1,080	N	12,560	11,080	1,880	12.8	—3.1	1.85	.04	.045
		13.1	D	1,020	4,020	1,060	H	13,380	10,930	2,230	12.8	—4.1	1.88	.11	.061
56	Lake Charles clay	1.9	T	1,250	4,750	470	H	12,400	9,030	330	12.7	—0.4	1.84	.00	B
		6.7	N	1,200	4,720	900	F	16,660	12,650	3,050	9.4	—6.1	1.94	.10	C
		9.1	N	950	3,970	150	J	12,310	10,700	380	12.7	—3.0	1.87	.04	C
		10.6	J	1,290	5,000	270	M	13,360	9,220	550	13.0	—3.0	1.86	.04	.130
		12.8	I	1,040	4,140	—130	..	..	....	....	17.9	0.0	1.75	.00	.140
58	Muck	1.9	V	1,275	5,060	940	R	11,340	8,820	460	12.9	—1.6	1.84	.01	D
		6.8	I	1,425	5,500	1,230	K	13,910	12,290	2,580	10.4	—6.7	1.90	.12	C
		9.1	J	1,290	5,000	270	T	13,180	10,280	2,140	11.9	—2.4	1.88	.04	C
		10.6	N	1,060	4,190	370	O	8,500	10,120	1,320	13.4	—3.0	1.82	.04	.043
		12.8	F	1,300	4,810	530	M	13,460	10,240	1,570	13.8	—2.2	1.85	.02	.047
59	Carlisle muck	1.9	V	1,350	5,610	1,500	Q	7,730	8,660	550	12.0	—1.9	1.89	.02	C
		7.0	N	1,200	4,860	1,020	B	13,120	11,350	1,940	10.4	—4.7	1.92	.10	C
		9.0	C	1,000	4,040	850	S	9,980	9,440	970	15.1	0.6	1.80	—.04	C
		10.6	A	1,160	4,890	690	M	13,260	10,490	1,820	13.9	—1.4	1.84	.01	.076
		13.0	B	1,250	4,840	300	B	11,770	10,420	1,010	13.7	—0.7	1.86	01	.106
60	Rifle peat	1.9	M	1,250	4,690	590	M	12,890	8,680	—10	14.8	—1.7	1.79	—.02	D
		7.0	G	1,375	5,490	1,180	D	8,500	7,510	—390	14.6	—2.8	1.79	.03	D
		9.0	A	950	3,950	—250	B	10,530	8,170	—1,240	14.1	—0.2	1.84	.00	D
		10.6	E	850	3,330	—610	T	10,620	7,820	—490	20.2	3.4	1.68	—.12	.212
		13.0	G	830	3,370	—940	I	10,590	7,410	—900	23.4	6.1	1.58	—.19	.202
61	Sharkey clay	1.9	E	1,375	5,490	1,550	A	7,990	9,940	—500	13.8	—1.8	1.85	.02	B
		6.8	H	1,350	4,850	410	V	12,710	11,770	2,820	9.2	—5.8	1.93	.09	C
		9.1	W	1,100	4,110	830	Q	10,330	10,230	2,120	12.3	—2.8	1.85	.04	C
		10.6	R	1,200	4,480	760	V	13,020	10,820	3,360	12.4	—2.6	1.87	.05	.040
		12.8	R	1,200	4,490	770	W	14,440	10,600	2,540	13.2	—1.6	1.84	.01	.038
62	Susquehanna clay	1.9	O	800	3,680	390	P	10,440	9,360	—200	12.3	—4.7	1.80	.06	B
		6.8	Q	975	3,950	590	C	12,730	11,340	2,750	9.8	—6.2	1.90	.11	B
		9.1	L	1,195	4,740	540	W	12,750	9,170	1,110	11.2	—3.6	1.88	.06	B
		10.6	U	1,190	4,850	740	K	15,520	11,990	2,280	11.9	—3.2	1.89	.05	.062
		12.8	V	1,220	4,730	610	S	12,500	10,870	2,400	11.9	—2.1	1.89	.05	.067
63	Tidal marsh	1.9	L	1,125	4,350	150	H	14,410	9,630	930	11.7	—4.1	1.88	.06	B
		6.7	E	1,200	4,830	890	E	12,860	10,780	2,020	9.6	—6.0	1.94	.11	B
		9.0	U	1,100	4,440	330	L	12,160	10,580	730	11.4	—3.4	1.90	.05	B
		10.5	O	1,110	4,790	1,500	R	14,360	11,900	3,540	11.6	—4.8	1.85	.08	.026
		12.7	U	1,330	5,360	1,250	R	13,000	11,850	3,490	10.3	—4.6	1.92	.09	.032
64	Docas clay	1.9	J	1,400	5,530	800	G	12,330	10,440	920	10.8	—4.7	1.91	.07	B
		6.9	I	1,125	4,590	320	S	13,760	11,730	3,260	8.6	—7.1	1.96	.16	A
		9.1	J	1,340	5,330	600	L	13,460	12,450	2,600	9.2	—6.4	1.94	.11	A
		10.7	O	960	4,260	970	T	14,030	10,800	2,660	9.4	—5.6	1.90	.11	.019
		12.9	C	950	3,800	610	N	13,820	12,210	3,010	9.2	—6.6	1.92	.11	.026
65	Chino silt loam	1.9	K	1,100	4,460	200	M	12,900	9,780	1,110	11.6	—4.7	1.85	.04	B
		6.9	Q	1,075	4,320	960	D	10,090	9,540	1,640	11.4	—5.8	1.86	.12	A
		9.1	U	1,195	4,710	600	B	16,630	12,890	3,480	10.2	—4.0	1.94	.08	A
		10.7	F	1,280	4,920	640	G	14,520	12,710	3,190	8.7	—7.3	1.94	.12	.022
		12.9	F	1,370	5,140	860	K	14,780	11,670	1,960	9.0	—7.0	1.94	.12	.026
66	Mohave fine gravelly loam	1.9	D	1,100	4,410	1,450	P	11,190	9,910	350	14.6	—3.4	1.80	.08	B
		6.9	I	1,350	5,420	1,150	T	14,180	10,510	2,370	8.6	—7.0	1.94	.15	A
		9.1	E	1,245	4,860	520	T	12,460	9,590	1,450	10.4	—4.0	1.92	.08	A
		10.6	G	1,500	5,910	1,600	..	....	....	....	10.0	—6.7	1.93	.13	.012
		12.8	W	1,240	4,660	1,380	U	12,580	11,530	2,580	9.0	—5.0	1.94	.09	.016
67	Cinders	1.9	O	800	3,560	270	A	9,570	9,850	—590	12.7	—4.3	1.80	.06	C
		7.0	R	1,325	4,840	1,120	F	12,210	9,560	—40	10.7	—4.9	1.90	.08	D
		9.0	S	1,245	4,870	610	Q	8,010	7,970	—140	14.9	0.0	1.78	—.03	D
		10.6	W	990	3,670	390	K	11,860	9,640	—70	12.1	—3.0	1.86	.04	.068
		13.0	K	1,130	4,420	160	J	13,460	10,490	170	12.8	—3.0	1.86	.04	.067
70	Merced silt loam	1.9	F	1,425	5,420	1,140	P	11,310	10,000	440	10.4	—4.9	1.90	.06	B
		6.9	M	1,375	5,140	1,040	D	8,260	8,230	330	9.7	—7.6	1.90	.13	A
		9.1	R	1,340	4,940	1,220	S	14,630	11,970	3,500	10.5	—4.2	1.91	.09	A
		10.7	A	1,150	5,150	950	E	14,200	12,650	3,890	9.5	—5.4	1.94	.08	.016
		12.9	Q	1,050	4,490	1,130	V	14,290	11,560	4,100	10.4	—5.0	1.90	.10	.018

[1] See Table 4 for properties of the unexposed specimens.

[2] Hydrostatic bursting and crushing tests were performed on air-dry specimens. Average dimensions: internal diameter, 3.99 ± 0.05-inch; wall thickness, 0.63 ± 0.10-inch; length of samples for crushing tests, 5.13+ 0.32 or —0.81-inch; length of samples for bursting tests, 11 inches.

[3] Data are for one specimen.

[4] Data are two measurements made on samples from one specimen.

[5] Average of 12 measurements made on 4 samples from the bursting test specimen and 8 samples from the crushing test specimen. Water absorption and apparent specific gravity measurements were not made on the specimens subjected to crushing tests for the 2-year exposures.

[6] Average of the maximum condition of the two specimens. Average thickness of the calendar layer is 0.02-inch. The values for the condition for the latter periods are the maximum depth of softening in inches. Condition of surface: A—hardening of the calendar layer; B—surface unchanged; C—softening to a maximum depth of 0.06-inch; D—softening to a maximum depth of 0.15-inch.

TABLE 3. Mechanical and Physical Properties of 6-Inch Asbestos-Cement Pipe After Exposure to Soils[1, 2]

SOIL No.	SOIL Type	Exposure	BURSTING STRENGTH[3] Bursting Pressure	Tensile strength	Tensile strength Difference from unexposed	CRUSHING STRENGTH[4] Crushing load	Modulus of rupture	Modulus of rupture Difference from unexposed	Water absorption[5]	Water absorption Difference from unexposed	Apparent specific gravity[5]	Apparent specific gravity Difference from unexposed	Depth of softening[6]
		Years	lb/in²	lb/in²	lb/in²	lb/linear ft.	lb/in²	lb/in²	Percent	Percent			In.
51	Acadia clay	2.1	995	4,980	170	12,440	10,770	110	7.3	—2.5	1.90	0.00	C
		9.0	1,025	5,130	320	10,170	9,800	—860	10.9	1.1	1.86	—.04	0.024
53	Cecil clay loam	2.1	1,140	5,460	650	14,150	13,630	2,970	8.6	—1.2	1.88	—.02	B
		4.0	1,010	5,080	270	10,840	10,970	310	7.3	—2.5	1.88	—.02	B
		8.9	950	4,860	50	11,120	11,630	970	7.1	—2.7	2.00	.10	.011
		11.2	1,000	4,860	50	13,480	13,340	2,680	8.2	—1.6	1.90	.00	.024
		12.7	1,025	5,100	290	12,650	11,420	760	10.4	0.6	1.82	—.08	.041
55	Hagerstown loam	1.9	1,085	5,400	590	12,130	12,560	1,900	10.0	0.2	1.84	—.06	B
		3.9	1,100	5,450	640	12,870	13,030	2,370	10.0	0.2	1.81	—.09	B
		9.0	1,150	5,820	1,010	10,290	9,890	—770	8.8	—1.0	1.92	.02	.017
		11.0	910	4,420	—390	13,180	11,450	790	11.1	1.3	1.80	—.10	.060
		12.6	825	4,100	—710	10,380	9,550	—1,110	10.4	0.6	1.83	—.07	.059
56	Lake Charles clay	2.1	995	5,070	260	13,140	13,010	2,350	5.6	—4.2	1.97	.07	B
		4.0	1,050	5,160	350	12,590	12,810	2,150	7.9	—1.9	1.86	—.04	C
		8.9	1,050	5,410	600	9,260	9,650	—1,010	7.5	—2.3	1.96	.06	.020
		11.1	935	4,600	—210	10,500	10,990	330	10.6	0.8	1.90	.00	.043
		12.7	900	4,510	—300	9,200	8,880	—1,780	15.2	5.4	1.78	—.12	.069
58	Muck	2.1	1,140	5,560	750	12,760	12,570	1,910	9.9	0.1	1.82	—.08	C
		4.0	925	4,630	—180	12,260	11,230	570	6.8	—3.0	1.89	—.01	C
		8.9	....	....	....	7,850	9,240	—1,420	7.6	—2.2	1.88	—.62	.021
		11.2	855	4,520	—290	9,220	9,390	—1,270	13.8	4.0	1.81	—.09	.048
		12.7	925	4,510	—300	10,170	9,120	—1,540	13.0	3.2	1.80	—.10	.053
59	Carlisle muck	2.1	1,255	6,070	1,260	12,050	12,200	1,540	8.7	—1.1	1.89	—.01	C
		4.0	1,215	6,340	1,530	11,730	11,540	880	9.0	—0.8	1.88	—.03	C
		9.1	1,125	5,830	1,020	11,540	10,530	—130	13.8	4.0	1.85	—.03	.035
		11.1	1,100	5,300	490	11,300	10,900	240	15.5	5.7	1.78	—.12	.043
		12.7	875	4,410	—400	9,760	8,550	—2,110	14.4	4.6	1.78	—.12	.089
60	Rifle peat	2.1	1,010	5,080	270	12,120	11,970	1,310	9.9	0.1	1.80	—.10	D
		4.0	1,165	5,770	960	12,120	11,330	670	8.8	—1.0	1.88	—.02	D
		9.1	1,125	5,760	950	9,920	10,070	—590	18.5	8.7	1.72	—.18	.110
		11.1	1,050	5,220	410	9,790	9,410	—1,250	18.4	8.6	1.74	—.16	.126
		12.7	900	4,360	—450	9,130	7,770	—2,890	16.6	6.8	1.74	—.16	.156
61	Sharkey clay	2.1	1,205	6,040	1,230	14,930	13,960	3,300	6.4	—3.4	1.91	.01	B
		4.0	1,065	5,330	520	9,690	10,710	50	5.1	—4.7	1.96	.06	B
		8.9	975	4,870	60	9,990	9,600	—1,060	12.2	2.4	1.82	—.08	.024
		11.2	1,000	4,760	—50	9,420	9,530	—1,130	13.3	3.5	1.85	—.05	.056
		12.7	1,075	4,930	120	11,150	9,560	—1,100	9.6	—0.2	1.88	—.02	.040
62	Susquehanna clay	2.1	1,095	5,410	600	15,650	14,460	3,800	5.9	—3.9	1.95	.05	B
		4.0	1,125	5,700	890	12,980	12,840	2,180	10.0	0.2	1.84	—.06	B
		8.9	900	4,570	—240	10,080	10,860	200	10.8	1.0	1.92	.02	.025
		11.2	1,125	5,450	640	12,700	12,630	1,970	10.8	1.0	1.90	.00	.029
		12.7	850	4,290	—520	9,000	8,330	—2,330	13.3	3.5	1.81	—.09	.052
63	Tidal marsh	2.1	1,175	5,620	810	17,370	14,680	4,020	10.4	0.6	1.84	—.06	B
		4.0	1,150	5,570	760	14,980	14,820	4,160	7.7	—2.1	1.90	.00	B
		8.9	775	4,290	—520	11,430	10,960	300	8.2	—1.6	1.86	—.04	.013
		11.2	1,000	4,940	130	12,720	11,960	1,300	13.3	3.4	1.86	—.04	.022
		12.6	1,025	5,030	220	10,200	9,980	—680	7.5	—2.3	1.93	.03	.024
64	Docas clay	2.1	1,100	5,810	1,000	14,410	13,900	3,240	6.3	—3.5	1.96	.06	B
		4.0	1,150	5,570	760	15,290	14,290	3,630	4.5	—5.3	1.96	.06	A
		9.0	750	3,930	—880	11,750	11,930	1,270	4.9	—4.9	2.06	.16	.010
		11.2	1,195	5,890	1,080	11,600	10,650	—10	5.8	—4.0	1.88	—.02	.028
		12.8	1,075	5,400	590	11,100	10,210	—450	7.4	—2.4	1.94	.04	.032
65	Chino silt loam	2.1	935	4,800	—10	15,980	15,750	5,090	7.0	—2.8	1.84	—.06	B
		4.0	1,070	5,420	610	13,160	12,300	1,640	6.3	—3.5	1.89	—.01	B
		9.0	975	4,990	180	11,680	11,290	630	5.3	—4.5	1.98	.08	.021
		11.2	1,125	5,400	590	13,650	12,640	1,980	6.4	—3.4	1.92	.02	.029
		12.7	1,125	5,510	700	10,990	9,610	—1,050	10.8	1.0	1.86	—.04	.035
66	Mohave fine gravelly loam	2.1	1,215	5,820	1,010	14,500	13,900	3,240	6.0	—3.8	1.94	.04	B
		4.0	1,240	6,210	1,400	13,680	14,470	3,510	6.2	—3.6	1.88	—.02	A
		9.0	1,075	5,470	660	11,110	10,710	50	10.3	0.5	1.88	—.02	.013
		11.2	1,100	5,460	590	....	....	....	8.9	—0.9	1.94	.04	....
		12.7	1,275	5,950	1,140	10,960	9,750	—910	12.0	2.2	1.86	—.04	.026
67	Cinders	2.1	1,030	5,100	290	15,650	14,680	4,020	7.2	—2.6	1.90	.00	C
		4.0	1,105	5,410	600	11,140	11,320	660	8.9	—0.9	1.85	—.05	D
		9.0	675	3,570	—1,240	11,270	11,430	770	12.0	2.2	1.85	—.05	.042
		11.2	910	4,680	—130	9,700	9,840	—830	15.4	5.6	1.80	—.10	.101
		12.7	800	3,900	—910	8,870	8,130	—2,530	17.3	7.6	1.73	—.17	.130
70	Merced silt loam	2.1	1,155	5,720	910	13,180	13,380	2,720	9.0	—0.8	1.86	—.04	A
		4.0	1,285	6,020	1,210	14,260	13,330	2,670	5.8	—4.0	1.92	.02	A
		11.1	1,025	5,220	410	12,790	12,730	2,070	6.4	—3.4	1.88	—.02	.033
		12.8	1,150	5,770	960	12,930	12,820	2,160	9.3	—0.5	1.90	.00	.057

[1] See Table 5 for properties of unexposed specimens.
[2] Hydrostatic bursting and crushing strength tests were performed on water-saturated specimens. Average dimensions—internal diameter, 5.93 ± 0.07-inch.; wall thickness, 0.72 ± 0.05-inch.; length of samples for crushing tests, 5.86 ± 0.13-inch.; length of samples for bursting tests, 12 inches.
[3] Data are for one specimen except as noted.
[4] Data are for two measurements made on one specimen except as noted.
[5] Average of 12 measurements made on 4 samples from the bursting test specimen and 8 samples from the crushing test specimen.
[6] Average of the maximum condition of the two specimens. Average thickness of the calendar layer is 0.02-inch. The values for the condition for the two latter periods are the maximum depth of softening in inches. Condition of the surface: A—hardening of the calendar layer; B—surface unchanged; C—softening to a maximum depth of 0.06-inch.; D—softening to a maximum depth of 0.15-inch.
[7] Average of measurements on four specimens.

computing the tensile strength according to the following modification of the Birnie formula[7] adapted to asbestos-cement pipe

$$f = \frac{P(d + 1.7t)}{2t}$$

where f = tensile strength in pounds per square inch
P = bursting pressure at failure in pounds per square inch
d = internal diameter in inches
t = wall thickness in inches

4.4 *Crushing Strength*

Determinations of crushing strength were made on lengths of pipe prepared by circumferentially cutting in half one specimen for each exposure period from each site. The values shown in Tables 2 through 5 are the averages of those obtained on two samples from each specimen. The tests were made according to the procedure described in Federal Specifications for asbestos-cement pipe,[8] using the three-edge bearing method. The load was applied at at rate of approximately 1,000 lb/min. until failure occurred. The directions of load application were 90 degrees apart for the two sections cut from the same specimen.

In order to take into account the normal dimensional variations in comparing the crushing strengths of the exposed and unexposed specimens, the modulus of rupture of the individual specimens was calculated from the values of crushing strength according to the formula given below. This formula, which is used generally in the asbestos-cement industry, is obtained by combining the standard ASTM formulas for crushing tests for application to the three-edge bearing method.

$$f = \frac{0.9P\,(d + t)}{Lt^2}$$

where

f = modulus of rupture in pounds per square inch
P = load to produce failure in pounds
d = internal diameter in inches
t = wall thickness in inches
L = length in inches

TABLE 4—Mechanical and Physical Properties of Unexposed Specimens of Air-Dry Asbestos-Cement Pipe 4 Inches in Diameter[1]

Designation of original pipe from which section was cut	Bursting strength		Crushing strength		Water absorption	Apparent specific gravity
	Bursting pressure	Tensile strength	Crushing load	Modulus of rupture		
	lb/in.²	lb/in.²	lb/linear ft	lb/in.²	Percent	
A	950	4,070	9,630	10,130	14.7	1.86
A [2]	1,000	4,330	10,570	10,760	13.6	1.84
B	1,120	4,440	11,770	9,410	14.1	1.86
B [2]	1,200	4,650	.....	.....	14.6	1.83
C	820	3,190	9,510	8,710	15.9	1.78
C [2]	.....	.....	10,270	8,710	15.0	1.81
C [2]	.....	.....	9,150	8,340	16.0	1.84
D	730	2,960	8,760	7,900	18.0	1.72
E	1,020	3,940	10,050	8,760	15.6	1.83
F	1,150	4,280	11,970	9,600	15.3	1.84
G	1,080	4,310	10,650	9,520	16.7	1.80
H	1,190	4,440	13,030	8,700	15.9	1.81
I	1,100	4,270	10,010	8,310	17.9	1.75
J	1,225	4,730	12,580	10,320	15.5	1.84
K	1,060	4,260	11,780	9,710	16.3	1.81
L	940	3,830	10,950	9,850	16.0	1.81
L [2]	1,100	4,570	.....	.....	15.6	1.83
M	1,100	4,100	11,760	8,670	16.5	1.81
N	950	3,730	12,120	9,200	16.1	1.80
N [2]	1,000	3,920	.....	.....	15.5	1.84
O	750	3,290	7,690	8,880	17.0	1.74
P	1,100	4,460	10,740	9,560	14.6	1.87
Q	790	3,360	8,390	8,110	16.3	1.78
R	1,000	3,720	9,050	8,360	15.9	1.79
S	1,050	4,260	11,100	8,470	13.5	1.85
T	1,100	4,280	9,850	8,140	13.1	1.84
U	1,000	4,110	11,240	8,950	13.9	1.87
V	1,050	4,120	9,600	7,460	14.5	1.83
W	750	2,860	9,910	8,450	14.6	1.81
W [2]	950	3,700	10,380	7,670	13.5	1.85

[1] Average dimensions—internal diameter, 3.99 ±0.05 in.; wall thickness, 0.64 ± 0.09 in.; length of samples for crushing tests, 4.13 +0.75 or —0.18 in.; length of samples for bursting tests, 11 in.
[2] Measurements made by the National Bureau of Standards. Measurements on the other reference specimens were made by the Pittsburgh Testing Laboratories and the research laboratories of the manufacturer.

TABLE 5—Mechanical and Physical Properties of Unexposed Specimens of Water-Saturated Asbestos-Cement Pipe 6 Inches in Diameter[1]

Specimen	Bursting pressure	Tensile strength	Crushing load	Modulus of rupture	Water absorption	Apparent specific gravity
	lb/in.²	lb/in.²	lb/linear ft	lb/in.²	Percent	
1	995	5,010	.....	.....	9.6	1.81
2	940	4,670	.....	.....	10.9	1.88
3	970	4,750	.....	.....	10.0	1.92
4a	...	.....	9,940	10,160	9.6	1.92
4b	...	.....	10,270	10,470	9.1	1.90
5a	...	.....	11,840	11,660	9.6	1.90
5b	...	.....	10,530	10,360	9.8	1.93
Average	990	4,810	10,640	10,660	9.8	1.90

[1] Average dimensions: internal diameter, 5.94±0.93 in.; wall thickness, 0.71± 0.05 in.; length of samples for crushing tests, 5.81 ±0.23 in.; length of samples for bursting tests, 12 in.

4.5 *Water Absorption and Apparent Specific Gravity*

After completion of the bursting and crushing tests, samples, approximately 4 inches in length and 2 inches in width, were cut from sound sections of the tested specimens for water absorption and apparent specific gravity determinations. Air-dried samples were immersed in water for 24 hours and weighed in water and in air, respectively. The specimens then were dried at 105 degrees C until a constant weight was obtained. The percentage of moisture absorbed and the apparent specific gravity were calculated as follows:

$$\text{Water absorption (in percent)} = \frac{(\text{wet weight in air}) - (\text{dry weight})}{\text{dry weight}} \times 100,$$

$$\text{Apparent specific gravity} = \frac{\text{dry weight}}{(\text{wet weight in air}) - (\text{wet weight in water})}.$$

5. *Mechanical and Physical Properties of the Exposed and Unexposed Samples*

The properties of the 4-inch and 6-inch specimens of asbestos-cement pipe removed from the test sites after five periods of exposure are given in Tables 2 and 3, respectively.

Because the properties of asbestos-cement pipe are normally subject to some variation, the values reported for individual specimens removed from a test site after different periods of exposure do not necessarily measure the effect of exposure for these periods. However, differences between the values for exposed and unexposed specimens cut from the same length of pipe may be taken to represent the effect of exposure for the selected period. The letter symbols given in Table 2 identify the pipe sections from which the samples of 4-inch pipe were cut. The values for

the unexposed specimens from which the differences in tensile strength modulus of rupture, water absorption and apparent specific gravity given in Table 2 were calculated are recorded in Table 4. The differences between the properties of the exposed and unexposed 6-inch specimens could not be calculated by this procedure because the sections of pipe from which these samples were cut were not recorded. Hence, it was necessary to make use of average values for the properties of the unexposed 6-inch samples (Table 5) in calculating the differences given in Table 3.

The values for water absorption and apparent specific gravity reported in Tables 2 and 3 represent the average of the measurements made on the samples which were subjected to the bursting and crushing tests. The differences between these average values and the averages of the measurements made on the samples of the unexposed pipe, from which the specimens were cut are also reported.

The values for depth of penetration given in Table 2 for the first three periods and in Table 3 for the first two periods of exposure are reported as ranges because a quantitative measure of penetration was not then available. The data reported for the later periods are strictly quantitative. In considering the value for depth of penetration, it should be noted that the external layers of unexposed asbestos-cement pipe to a depth of approximately 0.02 inch are normally somewhat softer than the underlying material because of the method of manufacture. Consequently, values up to 0.02-inch reported in the table are not to be taken as the result of exposure to the soils.

The values for depth of penetration should not be interpreted to mean that the effect of exposure to the soils was necessarily confined to the softer layers because comparison of the quantities of water absorbed by specimens with the original surface intact and after removal of the softened layers revealed no significant differences. These data were given in the previous report.[4]

In the photographs of the cross sections of the samples, Figure 1, the depth of softening is indicated by the thickness of the dark layers. The specimens had been exposed to the soils indicated in the figure for approximately 13 years.

The data presented in Tables 2 and 3 will be discussed in detail later. For the present, it is sufficient to note that the bursting and crushing strengths of the samples, both before and after exposure, were without exception considerably greater than the requirements of the Federal Specifications for this class of material.[8] Federal Specifications for asbestos-cement pipe require that the pipe be tested under hydrostatic pressure of three and one-half times the maximum working pressure for the given class of pipe. For example, samples of pipe of class 150 are required to withstand a hydraulic pressure of 525 lb/in.[2] The specifications also require that pipe sections tested by the three-edge bearing method shall not fail until the crushing load exceeds 5400 lb/linear ft. for 4-inch and 6-inch pipe of class 150.

The changes in strength of the 4-inch and 6-inch specimens during exposure to the different soils are shown graphically in Figures 2 and 3, respectively, in which the differences in tensile strength and modulus of rupture between the exposed and unexposed specimens are plotted against the duration of exposure. The differences between the amount of water absorbed by the unexposed specimens and those exposed for the different periods are shown in Figures 4 and 5, respectively. Comparison of the curves

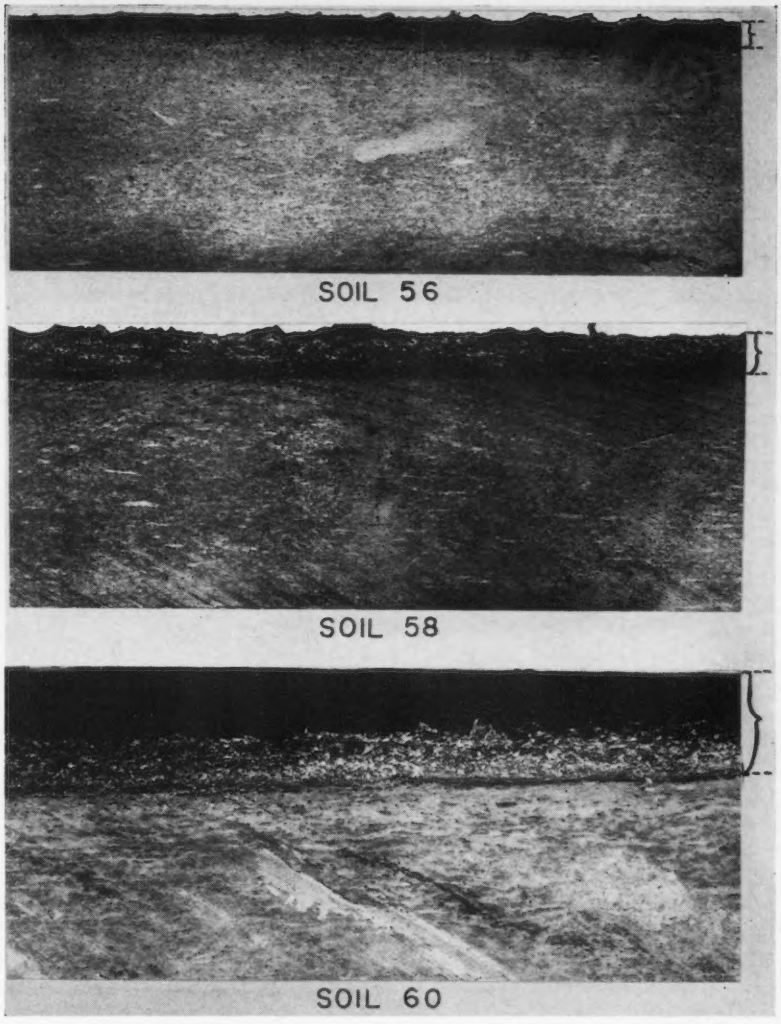

Figure 1—Cross sections of asbestos-cement pipe exposed in different soils for 13 years. X 3. The depth of softening is indicated by the thickness of the dark layers shown by the brackets.

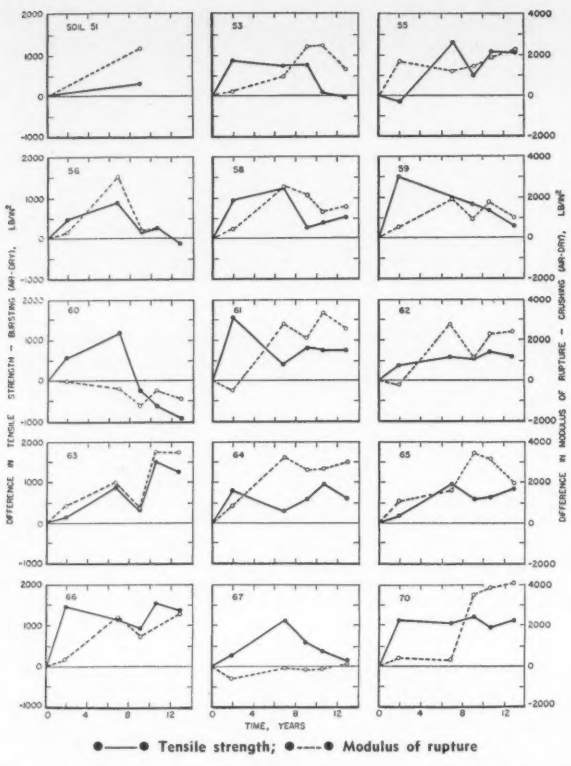

Figure 2—Differences in tensile strength and modulus of rupture between unexposed specimens of 4-in. pipe and similar specimens exposed underground for different periods. The properties of the soils are given in Table 1.

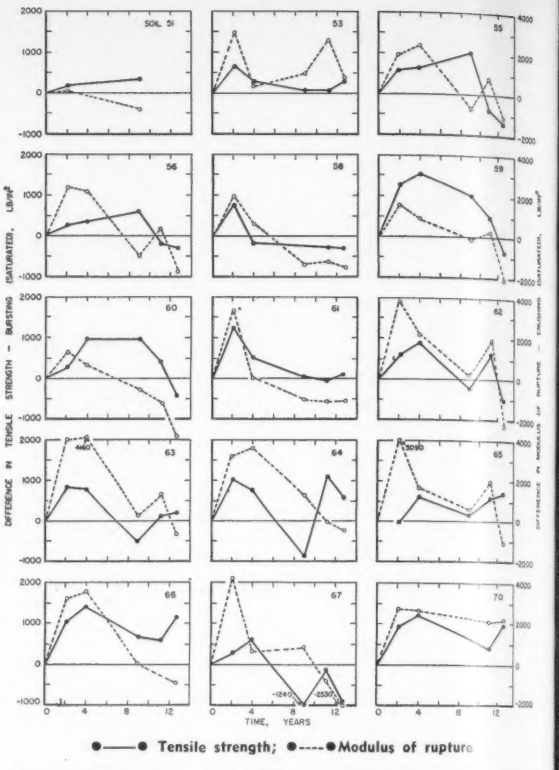

Figure 3—Differences in tensile strength and modulus of rupture between unexposed specimens of 6-in. pipe and similar specimens exposed underground for different periods. The properties of the soils are given in Table 1.

in Figures 2 through 5 show, in general, that increases and decreases in strength as indicated by the bursting and crushing strength measurements are associated with the decreases and increases, respectively, of the amount of water absorbed.

In general, the curves indicate an increase in strength during the early periods of exposure followed by a decrease in strength during the remaining periods. The increased strength observed during the early periods of exposure is associated with a curing process that continued after exposure to the soil. The maximum values shown by the bursting and crushing strength-time curves, and the minimum values by the water absorption-time curves indicate the completion of the residual curing of the asbestos-cement pipe. The sections of the curves to the right of these points may be considered to represent the effect of weathering resulting from the action of the elements in the soils in altering the asbestos-cement. Therefore, a comparison of the heights of these curves to the right of these points is a relative measure of the extent of weathering and their slopes the rate of weathering in a selected soil.

The curves for the 4-inch specimens of asbestos-cement (Figure 2) indicate a high degree of resistance to deterioration in all the soils except in the organic soils 58, 59 and 60; in the organic soil high in organic content (56), the cinders (67) and in soil 53. The asbestos-cement pipe did not show the same high resistance to deterioration in inorganic acid soil (53) as it did in the other two inorganic acid soils (55 and 62). Although the high strength maintained by the 4-inch specimens might be taken to indicate that asbestos-cement is resistant to tidal marsh (soil 63), this inference is not supported by the behavior of the 6-inch specimens in this soil (Figure 3). The greater losses in strength for the 6-inch specimens also generally occurred in the soils high in organic matter.

A comparison of the data for the 4-inch and 6-inch specimens show that weathering after the completion of the curing process, has progressed at a faster rate in the larger than in the smaller size pipe.

Cement products are altered by the process of hydrolysis and the rate of alteration is accelerated by hydrogen ions, which are present in soils as carbonic acids. Since the decomposition of organic matter provides a large amount of carbonic acid to the ground water, and so increases its activity, relatively greater losses in strength of portland cement would be expected in soils high in content of organic matter. The curves which show the differences between the amount of water absorbed by the unexposed specimens and those exposed for different periods for the 4-inch specimens (Figure 4) are consistent with this view. For example, in the alkaline soils 64, 65, 66 and 70, in which the concentration of free carbon dioxide is negligible, the 4-inch specimens show no definite tendency to absorb increasing amounts of water with increase in time of exposure. The data

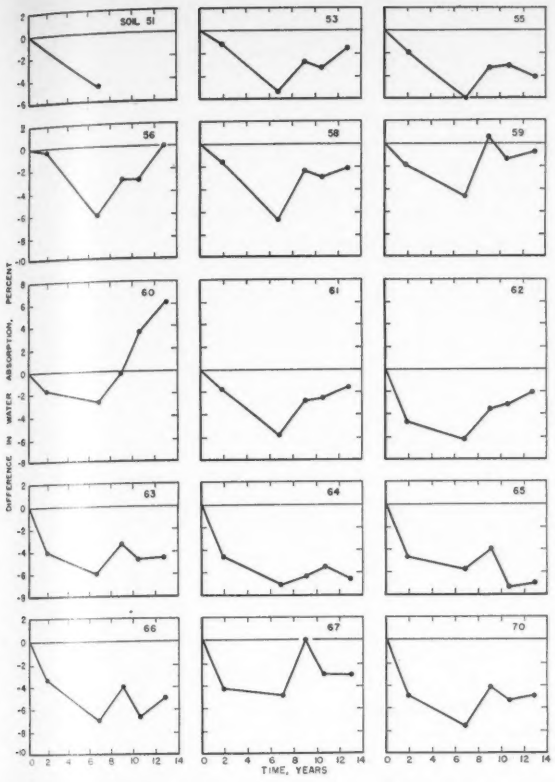

Figure 4—Differences in amount of water absorbed between unexposed specimens of 4 in. asbestos-cement pipe and similar specimens exposed underground for different periods.

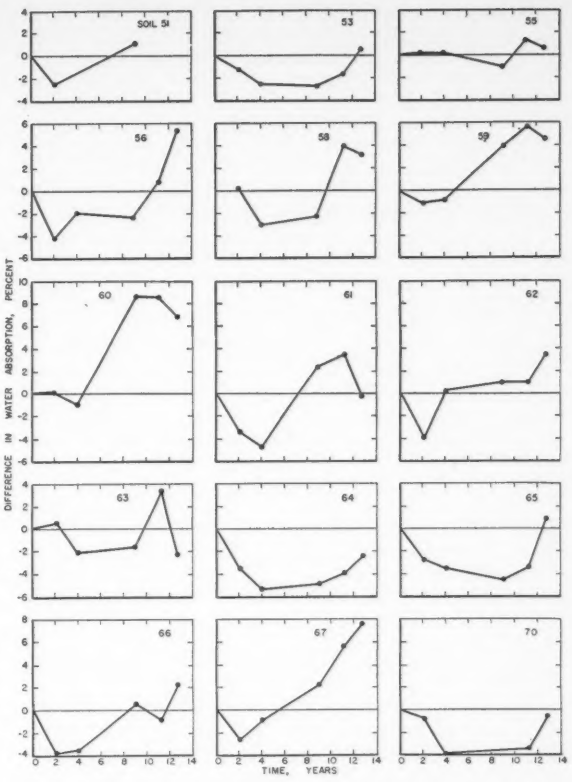

Figure 5—Differences in amount of water absorbed between unexposed specimens of 6-in. asbestos-cement pipe and similar specimens exposed underground for different periods.

for the tensile strength and modulus of rupture (Figure 2) show that the rate of weathering of the water-cured asbestos-cement in these soils is very low. On the other hand, in the acid inorganic soils (53, 55, 61 and 62), in the organic soils (58, 59 and 60) and in the inorganic soils high in organic matter (56), all of which contain hydrogen ions or ionizable hydrogen in relatively high concentration, progressive absorption of water with time is generally indicated by the data (Figure 4). This is consistent with the curves in Figure 2 which indicate that weathering of asbestos-cement proceeds in these soils at an appreciable rate. Marked absorption of water and a correspondingly high rate of incipient deterioration is indicated by the data for the extremely acid soil 60 (pH 2.6). The slight tendency for water to be absorbed by the specimens in the organic soil 63 and in cinders (67) are not consistent with this explanation.

The water absorption curves for the 6-inch pipe (Figure 5) show similar tendencies as noted for the 4-inch pipe, except that weathering of the 6-inch specimens generally has progressed at a greater rate after completion of the residual curing period during exposure to the soils. The behavior of the 6-inch specimens in soils 63 and 67 are consistent with previous explanations.

The overall effect of exposure to the soils on the 4-inch and 6-inch samples of the asbestos-cement pipe is indicated in Figures 6 and 7. In preparing the curves shown in the figures, the values for tensile strength, modulus of rupture, percentage of water absorbed and apparent specific gravity in all of the soils, excepting soil 51 because of insufficient data, were averaged for each period of exposure and for each size of asbestos-cement pipe. The standard deviations of these mean values are also indicated in the figures. The data for the 4-inch specimens (Figure 6) were adjusted to the water-saturated condition by reducing the values for tensile strength and modulus of rupture by 15 percent; this is the average difference in strength between the water-saturated and the air-dry condition.[5]

The average tensile strength of the 4-inch pipe (Figure 6) increased about 700 lb/in.^{2} during the exposure periods of two and seven years but thereafter the trend was for its tensile strength to decrease slightly as the time of exposure increased. However, its tensile strength after exposure of 13 years was still higher than that of the unexposed pipe.

The modulus of rupture of the 4-inch pipe also showed the general trend to increase with exposure time up to seven years and then to remain constant with further exposure. The attainment of the maximum values for rupture and tensile strengths in the specimens exposed for seven years indicate that the residual curing of the pipe was completed in this time. That the curing of the 4-inch pipe is complete in seven years is also indicated by the positions of the maximum in the specific gravity-time curve and the minimum in the water absorption-time curve.

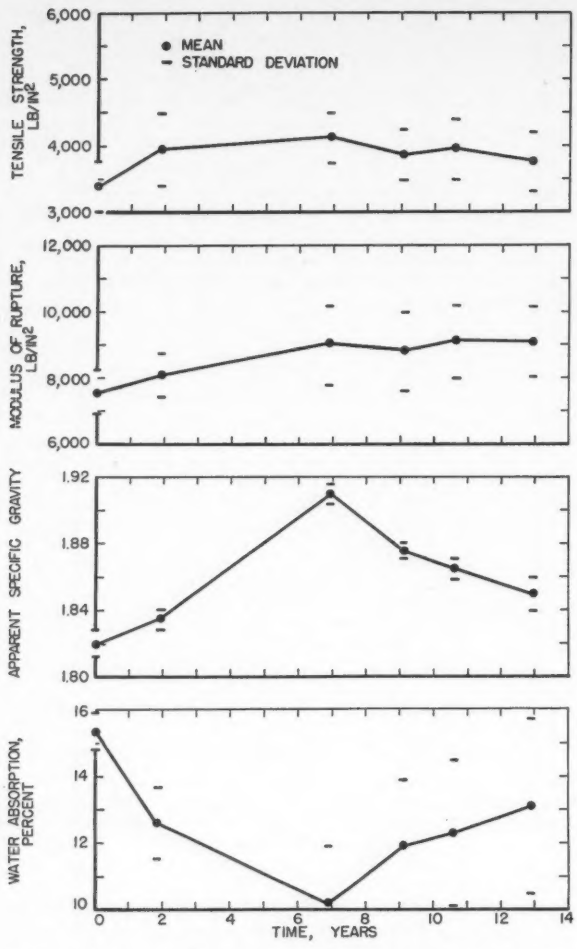

Figure 6—Average tensile strength, modulus of rupture, apparent specific gravity and water absorption of 4-in. specimens in 14 soils for different periods of exposure. Data for the tensile strength and modulus of rupture adjusted to the saturated condition.

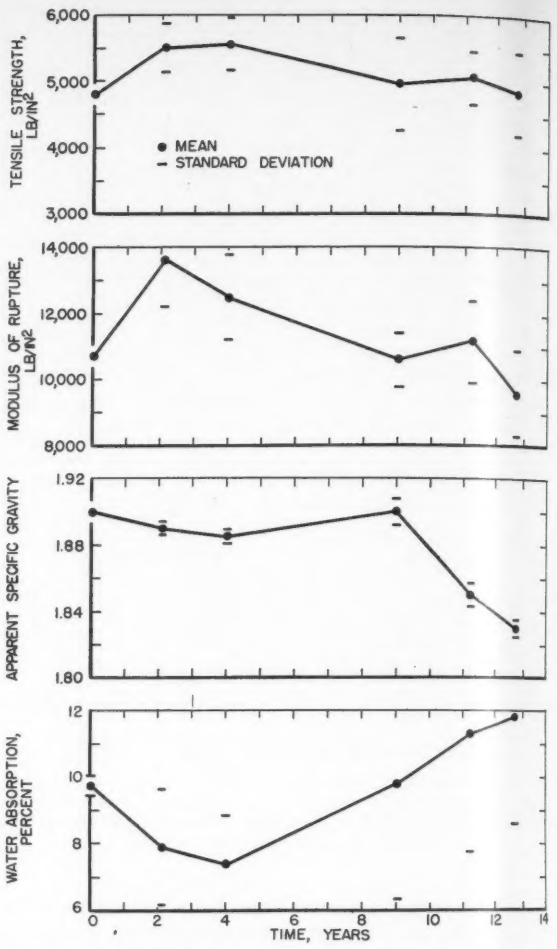

Figure 7—Average tensile strength, modulus of rupture, apparent specific gravity and water absorption of 6-in. specimens in 14 soils for different periods of exposure. Measurements of tensile strength and modulus of rupture made on specimens in the saturated condition.

The average tensile strength of the 6-inch pipe (Figure 7) increased during the exposure periods of two and four years and was then followed by a decrease in strength during the remaining periods. Its tensile strength after exposure of 13 years was of the same order of magnitude as that of the unexposed pipe.

The time curves for the modulus of rupture and water absorption of the 6-inch pipe indicate an increase in strength and a decrease in water absorption up to the 2-year and 4-year periods of exposure, respectively, and thereafter show a decrease in strength and an increase in water absorption for the remaining periods. The curve for the apparent specific gravity does not show any signficant change until the 9-year exposure period, which is followed by a decrease in density.

The results of measurements made of the tensile and crushing strengths and water absorption indicate that the curing period was two to four years in the 6-inch pipe. Thus, the curing process of asbestos-cement pipe was completed in a shorter time in the 6-inch steam-cured than in the 4-inch water-cured pipe (approximately, 2 to 4 and 7 years, respectively).

A comparison of the data given in Figures 6 and 7 show that both the tensile and rupture strengths of the unexposed specimens were higher for the 6-inch steam-cured than for the 4-inch water-cured pipe. The 6-inch pipe also appears to be a denser material, as is indicated by the higher initial values of apparent specific gravity and low values for water absorption, as compared with the water-cured 4-inch specimens. However, it should be noted that the differences in strength between the two materials can not be ascribed solely to the different processes of curing because of the differences in dimensions, composition of cement, and in the method of fabrication of the two varieties of pipe.

Hansen[9] reviews the literature on the chemical reactions and changes which may occur during the curing of portland cement products at ordinary temperatures and at the elevated temperatures in steam curing. According to the report of the Committee 716 of the American Concrete Institute,[10] higher strength properties, more stabilized form and increased resistance to sulfate are obtainable for cement products

with high pressure steam curing than by the damp curing process. It states that while high strength developed in a few hours of steam curing is in part due to the acceleration of the normal process of hardening, a material contribution to strength comes from the reaction resulting in the formation of a hydrated calcium silicate from the lime and silica present. The more stabilized form of cement attributable to pressure steam curing results, in part, from the conversion (or partial conversion) of the amorphous calcium silicates to crystalline forms, which do not swell or shrink as much as do the amorphous forms with increase or decrease in moisture content. It also has been observed by the Committee that the series of compounds that are known as hydrogarnets, which result from steam curing of cement products, are very stable and highly resistant to the action of sulfate solutions.

6. Summary

This report deals with the effect of exposure to 15 different soils on the physical and mechanical properties of samples of asbestos-cement pipe exposed for periods up to 13 years. Samples of both water-cured and steam-cured pipe were included in the tests. Measurements of the hydrostatic bursting pressure, crushing strength, water absorption and apparent specific gravity of the samples exposed for periods of increasing length show that the curing process continues for several years after exposure underground. Following this period of cure, asbestos-cement is subject to weathering which is manifested by loss in strength, decrease in apparent specific gravity, by increased absorption of water and by superficial softening.

The rate and extent of alteration of the samples were affected by the nature of the soil conditions to which the samples were exposed. The weathering of asbestos-cement pipe is accelerated by both organic and inorganic acidity. However, even under the most adverse conditions to which the specimens were exposed, the bursting and crushing strengths of all of the samples after exposure were considerably higher than the requirements of the Federal Specifications for asbestos-cement pressure pipe.

The field tests described in this paper were initiated, installed and, until 1946, were conducted by K. H. Logan. The material assistance received from the Johns-Manville Corporation and the Keasbey and Mattison Company is acknowledged.

7. References

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3. Kirk H. Logan, Underground Corrosion. NBS Circ. C450 (1945).
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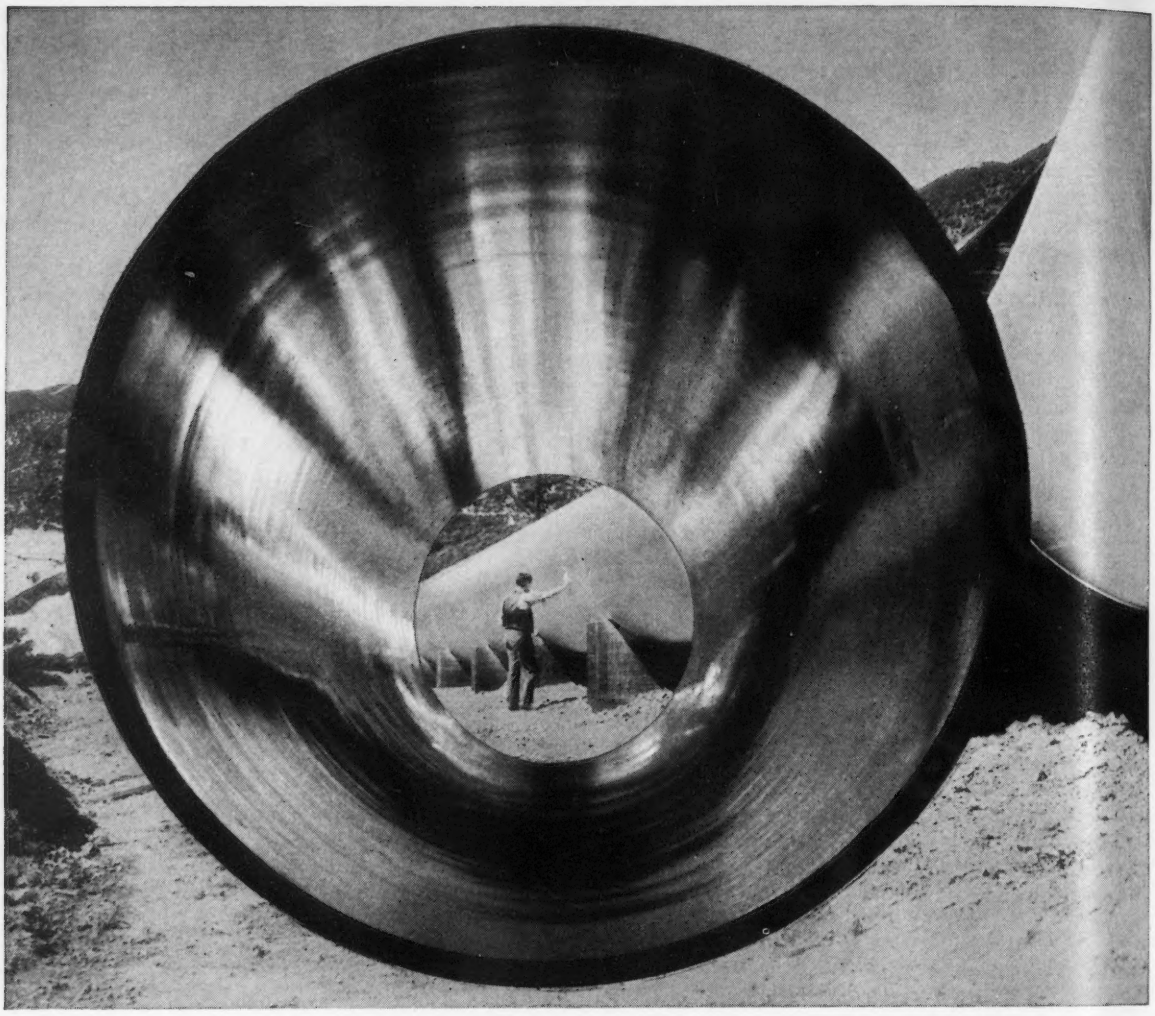

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BARRETT PROTECTIVE COATINGS

Topic of the Month

A New Accelerated Corrosion Device

By S. K. COBURN*

AMONG CORROSION scientists it is generally agreed that field testing, despite the lengthy time period involved is the preferred procedure for judging the corrosion resistance of structural materials. Unfortunately, the lack of control of known variables and the action of unknown atmospheric factors often vitiate what otherwise might be considered useful information. A laboratory test which permits precise control of known variables with a minimum of attention is always a welcome addition to the armamentarium of the corrosion investigator. The General Motors Research Laboratories has developed a new type of precision corrosion test to study the resistance to a corrosive environment of bare steel specimens where the formation of protective rusts is not realized.[1] One problem confronting the automotive industry is corrosion in sheltered areas such as exist inside doors and confined spaces of the automobile underbody. Rusting in these areas is continuous because the constant presence of moisture inhibits the formation of protective films. This situation is further aggravated by the presence of salt picked up as a result of municipal deicing operations during winter months, and the action of sulfur compounds present in industrialized communities.

In the development of this test, advantage was taken of the following two naturally occurring phenomena which lead to accelerated corrosion: 1) The relative humidity in most geographical regions varies during the course of a day. 2) The temperature of bare steel often reaches 125 degrees F in the sun while moist on the opposite face. These two factors in conjunction with an electrolyte comprise the basis of the test. The exposure of steel coupons to these conditions results in the production of a brittle, nonprotective lamellar type of rust. Figure 1 shows a corroded steel test panel with rust partially removed. The test is carried out over a 20-day period utilizing three 8-hour cycles per day in which the relative humidity is varied from 10 through 100 percent resulting in approximately 60 corrosion cycles. The electrolyte is composed of one percent sodium chloride, one percent calcium chloride and 0.1 percent by weight of sulfuric acid.

The test apparatus consists of a humidifying and heating system, a corrosion chest and a dipping mechanism. The relative humidity in the chest through the range of 100 to 50 percent is controlled by passing air through water whose temperature is varied under thermostatic control. Lower humidities are effected by passing air through dessicating towers of sulfur acid and activated alumina. The test coupons measure 1½ x 3 x 0.035-inch, have ⅜-inch holes punched at the short ends and are supported by glass rods in a rack which is suspended in the corrosion chest. The chest is constructed of stainless steel coated with a baked resin and surrounded by a heating cabinet maintained at 125 degrees F ± 2 degrees F. The relative humidity of the air can be ascertained at any time by virtue of its passing over

(Continued on Page 2)

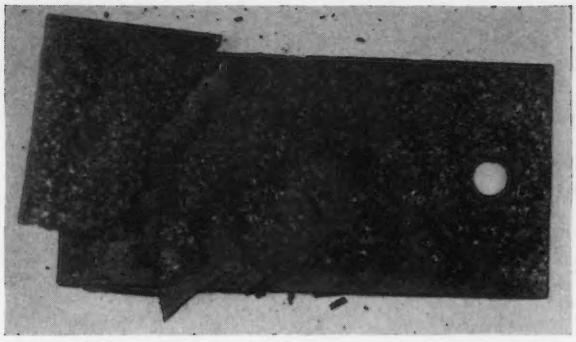


Figure 1—Corroded panel with rust partially removed.

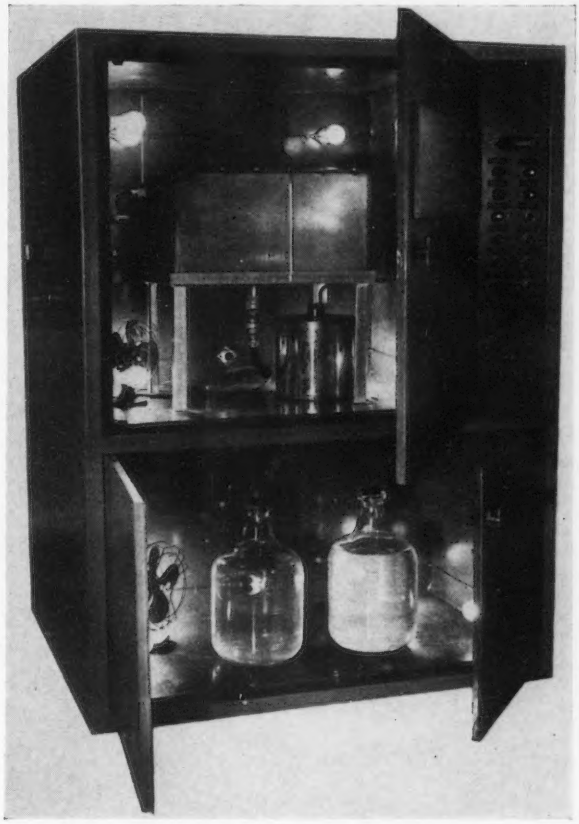
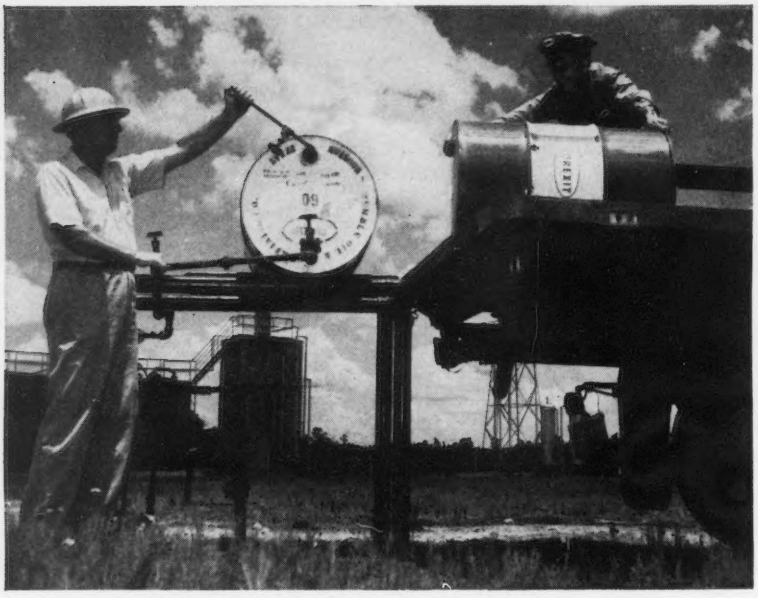


Figure 2—Corrosion test cabinet.

* Chemical Engineer, Association of American Railroads, Chicago 16, Ill.



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(Continued From Page 1)

a wet and dry bulb hygrometer. While this instrument is not precise, it does serve as a check on the cycling of the test. Figure 2 shows the corrosion chest enclosed in the heating cabinet. The electrolyte is preheated in a separate cabinet below. The dipping or immersion mechanism is a leveling bottle which introduces the electrolyte through a drain at the bottom of the corrosion chest. This operation is performed manually in a manner to obtain a soaking, washing and draining action on the steel coupons. The dipping requires thirty minutes each day and is about the only attention required. After 20 days' exposure the steel coupons are descaled cathodically in inhibited sulfuric acid solution. Loss in weight per unit area is used for comparing materials.

Use of conventional salt spray equipment leads to corrosion losses only 30 percent of that obtained in the new test. Comparison of data obtained in this test with that developed in field exposure tests, where protective rusts have an opportunity to form, requires care in evaluation. Where the objective is to assess the value of a large number of materials in a minimum time this test should prove valuable.

REFERENCE

[1] A. J. Opinsky, R. F. Thomson and A. L. Boegehold. Amer. Soc. Testing Mat. Bull., No. 187. January, 1953.

Electrodeposition Papers Scheduled

Papers with corrosion interest scheduled for presentation during the April 21-24 Fourth International Conference on Electrodeposition at London, England include:

On the Experimental Methods for the Determination of Electrode Polarization by R. Piontelli, Politechnica di Milano, Italia.

The Diffusion of Chromium and Other Elements into Non-Ferrous Metals by R. L. Samuel and N. A. Lockington, Diffusion Alloys, Ltd.

Recent Advances in Manufacture of Tinplate by W. E. Hoare, Tin Research Institute.

Automotive Body Finishing, J. T. O'Reilly, Ford Motor Co., Ltd.

Infra-Red Stove Drying of Paints, Peugeot, France.

Organic Finishes by Electrodeposited Coatings with Special Reference to Adhesion by E. C. J. Marsh, Standard Telephones and Cables, Ltd.

Glass-Fibre Reinforced Plastics: A New Material of Construction for the Finishing Industry by H. Silman, Ford Research Centre, U. K.

British Industries Fair

Plastic moldings for industrial fans which must be able to resist acids, alkalis and most gases will be illustrated by phenolic-type moldings and moldings of polyvinyl chloride at the British Industries Fair, London and Birmingham, England, May 3-14.

Vol. 10

NACE News

Northeast, Southeast Regions to Meet on May 6

Pittsburgh Session Includes Steel Plant Tour, Motion Pictures

Registration for the May 6 Northeast Region 1954 Spring Meeting will begin at 10 am at Hotel Webster Hall, 4415 Fifth Ave., Pittsburgh. This is opposite Mellon Institute.

The tentative program for the meeting is as follows:

12:40 pm—Bus leaves Webster Hall.

1:30 pm—Bus arrives at Allegheny Ludlum Steel Corp., Brackenridge, Pa. Tour starts at the main gate and finishes at the research laboratory.

3 pm—Guest speaker at the plant, William G. Renshaw, will have as his topic: Resistant Materials—Titanium, Zirconium.

4 pm—Bus leaves for return trip to Hotel Webster Hall.

8 pm—Evening meeting at Mellon Institute. First showing of a color motion picture "Al Si Mg Impurity Elements in Magnesium Alloy Cast Anodes."

8:30 pm—Guest speaker P. F. George, The Dow Chemical Company, "The Effect of Alloying and Impurity Elements in Magnesium Alloy Cast Anodes."

9:15 pm—Guest speaker, W. F. Fair, Jr., Koppers Company, Inc., on "Coal Tar Protective Coatings."

Schenectady-Albany-Troy Section Loses Chairman

Because of the sudden death March 13 of A. C. Mengel, chief chemist of American Locomotive Company, chairman of and founder of the Schenectady-Albany-Troy Section, the March 23 dinner meeting of the section was presided over by E. L. Simons, vice-chairman. Mr. Mengel, who was 60 at the time of his death, was active in civic and professional affairs.

The dinner meeting, attended by six members and two guests, heard Trafford W. Bigger, General Electric Company, speak on Corrosion in the Moisture Region of Large Steam Turbines.

A meeting is planned for June.

Greco Is Elected by South Central Region

At a meeting of the South Central Region Board of Trustees during the 10th Annual Conference and Exhibition of NACE, E. C. Greco was selected to fill the unexpired term of Clifford L. Barr as vice-chairman of South Central Region.

NACE MEETINGS

CALENDAR

May

5—Greater Boston Section. Cathodic Protection, speaker to be named.
11—Houston Section.
18—Cleveland Section. R. B. Seymour, Atlas Mineral Products Co., Allerton Hotel.
20—Chicago Section. Round table discussion.
25—Central Oklahoma Section. YWCA, Oklahoma City.
Southwestern Ohio Section. R. L. Featherly, The Dow Chemical Co., "Cathodic Protection."
27—Detroit Section.

June

8—Houston Section. Social meeting.
11—Detroit Section.

Tulsa Short Course Planned for February 16-18

The Sixth Annual Corrosion Short Course for Pipeliners will be given by Tulsa Section, National Association of Corrosion Engineers February 16-18, 1955 at Tulsa, Oklahoma with headquarters at the Mayo Hotel.

Thomas M. Ragland, Phillips Petroleum Company is chairman of the course.

Chicago Section Talks on Corrosion in Homes

Factors contributing to the corrosion of structures, fixtures and finishes in the home were discussed by a panel at Chicago Section's March 23 meeting. Practical means of reducing corrosion in the home were considered.

The program is a beginning by Chicago Section of a plan to examine and classify corrosion damage in dewellings and to examine possible remedies. The section has in mind at a coming "Ladies' Day" to present a classification of problems and remedies.

V. J. Payton, Commonwealth Edison Company was moderator and panel members were Chester Anderson, The Crane Company, piping and fixtures; L. P. Lessard, Johns-Manville Company, building materials; C. P. Larrabee, United States Steel Company, equipment and materials; Norris Bishton, Sherwin-Williams Company, finishes; H. V. Kelly, Aluminum Company of America, equipment and building materials and R. S. Wise, National Aluminate Corp., water treatment.

Three Papers Will Be Given at One-Day Birmingham Event

Three papers, a film on pipeline coating and a guided tour through an aircraft manufacturing plant are scheduled for the May 6 Southeast Region Spring Meeting to be held at the Georgia Hotel in Atlanta.

The schedule for the meeting has been set tentatively as follows:

8:00 a.m.—Registration. Fee $5, includes dinner and transportation to Lockheed plant.
8:30 a.m.—Barrett Division film on lining and coating a large diameter water pipe line.
9:00 a.m.—Comparative Cost of Magnesium Anodes versus Rectifiers on Coated Pipelines, Henry Allen, Allen Cathodic Protection Company, Harvey, La.
9:45 a.m.—Chemical Aspects and Uses of Saran, Stewart Blackmore, Dow Chemical Co., Detroit. Introduction by Hugo Jahnz, Jr., Southern Corp., Charlotte, S. C.
10:45 a.m.—Fiberglas in Corrosion Control of Underground Pipe Lines, John B. Roadhouse, Owens-Corning Fiberglas Corp., Toledo. Film: Lakehead Pipe Line.
11:30 a.m.—Lunch, Town House.
12:45 p.m.—Assemble at hotel for trip to Lockheed Aviation Corp. plant at Marietta, Ga.
1:30 p.m.—Inspection trip, Lockheed plant.
5:00 p.m.—Business meeting.
5:30 p.m.—Fellowship Hours.
6:30 p.m.—Dinner.
7:30 p.m.—Panel discussion of morning papers.

Miami Section Sees Film at First Meeting

First meeting of Miami Section of NACE was held at 8 pm Friday, February 26, in the Blue Flame Room of the People's Water and Gas Co., North Miami, Fla. The meeting was opened by Joe Prime, Miami Section chairman. Joe Frink, vice chairman, explained the organization activities and objectives of NACE, after which the film, Corrosion in Action was shown. Final activity of the night was the formation of four committees: Program and Refreshment, Underground, Above Ground and Testing.

Next meeting will be a combined meeting with the Jacksonville (Fla.) Section at Miami.

New Officers Installed By Los Angeles Section

The 1954-1955 officers for the Los Angeles Section were installed March 24. Sid K. Gally, chairman, Edward H. Tandy, vice-chairman and John R. Brown, secretary-treasurer were presented by S. J. Artese, retiring chairman.

L. L. Whiteneck, Western Regional Director of NACE, gave a brief report on the business sessions of the NACE National Conference in Kansas City. The speaker of the evening, Charles Anderson, Chief Engineer of Electro-circuits, Inc., presented an illustrated discussion of "Ultra-Sonic Testing of Metals" and a color film showing his plant's facilities and product developments. Mr. Anderson described the use of sound in helping corrosion engineers in detection and mitigation of corrosion problems. He said that this non-destructive procedure for testing provided the corrosion engineer with a device that can be used to test metals before use and during normal service. It may also be used on metals ranging from thin sheets to 30 inches in thickness and on band ranges up to 3 inches wide, depending upon the size of the crystal scanning head. Mr. Anderson described briefly the ultra-sonic testing procedure and presented slides showing typical applications of the test units demonstrating a wide versatility of the test methods.

The enthusiasm shown by the 62 members and guests present in the discussion following Mr. Anderson's talk indicated interest in the subject.

MEMBERS OF PANEL ON CORROSION OF HOME STRUCTURES are shown here at a meeting of Chicago Section March 23. Corrosion of home structures, fixtures and finishes and practical means of reducing losses were discussed. Left to right: R. S. Wise, National Aluminate Corp., water treatment; L. P. Lessard, Johns-Manville Co., building materials; Norris Bishton, Sherwin-Williams Co., finishes; Victor J. Payton, Commonwealth Edison Company, moderator; C. P. Larrabee, U. S. Steel Corp., equipment and materials; Chester Anderson, The Crane Co., piping and fixtures, and H. V. Kelly, Alcoa, equipment and building materials.

AT TULSA SHORT COURSE—This group was photographed during the annual Tulsa Section Short Course on Corrosion February 17-19. They are, left to right, Gaines Laster, Tulsa Pipe-Coating, Inc.; Wm. P. McCollister, Phillips Petroleum Co.; Earl O. Owens, T. D. Williamson, Inc.; A. L. Stegner, Tennessee Gas Transmission Co.; L. W. Phinney, International Rectifier Corp. and M. C. Callaghan, Gulf Pipe Line Company.

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Local Technical Group Weighed at Pittsburgh

The possibility of organizing a local technical committee among members of Pittsburgh Section was discussed April 1 at a dinner meeting attended by 42 members and four guests. Officers proposed by the nominating committee for 1954-55 were approved as follows: Wayne W. Binger, Aluminum Company of America, New Kensington, Pa., chairman; William G. Renshaw, Allegheny Ludlum Steel Corp., Brackenridge, Pa., vice-chairman; Louis G. Royston, Royston Laboratories, Inc., Blawnox, Pa., secretary and Wallace P. Cathcart, Tank Linings Corp., Pittsburgh, treasurer.

Mars G. Fontana, Ohio State University, Columbus, spoke on Corrosion and Its Prevention.

The remainder of the meeting was devoted to planning the May 6 Northeast Region Spring Meetings.

Edmonton Section

G. M. McPherson, secretary-treasurer, of the Canadian Region reports that the board of trustees of the Canadian Regional Division has approved a petition submitted by members of NACE in the Edmonton area for the formation of an Edmonton Section.

F. W. Hewes is acting chairman of the newly formed section.

Instruments Discussed At Oklahoma City

A demonstration of the application and use of various cathodic protection instruments was presented to members of the Central Oklahoma Section at its regular monthly dinner meeting in the YWCA building, Oklahoma City, March 23. Jim Cowles, Agra Instrument and Engineering Co., was the speaker. At the business session, Charles Kopp, section chairman appointed a membership committee of M. L. Steffens, George Evan and Alvin Teal. Mr. Kopp also appointed a correlating committee composed of Leroy Minnick, L. S. Waldrip and Don Sanders. A new member was welcomed.

Corpus Christi Section Installs New Officers

During the March 23 meeting of the Corpus Christi Section the following officers were installed for the 1954-1955 term: John Westervelt, chairman; Ray Pfrehm, vice-chairman; Paul Laudadio, secretary-treasurer.

Roy Comeaux, of Humble Oil & Refining Company, presented a paper covering the problems involved in cathodically protecting a large refinery which promoted many questions and much discussion.

Pipe Line Panel and Picnic Planned by Houston NACE Section

Planning technical programs in accordance with the expressed wishes of its members, the Houston Section has arranged a Panel on Current Pipe Line Corrosion Problems. O. W. Wade, Transcontinental Gas Pipe Line Corp., will be chairman of the panel.

Preliminary plans for the last meeting of the year, June 8, were enthusiastically received. The meeting will be a barbecue picnic held at the Diamond Alkali recreation grounds. Playground equipment, a swimming pool and other facilities will be enjoyed by section members and their families.

The April 13 meeting presented a Panel on Metallurgy in Corrosive Environments. Charles G. Gribble, Jr., Metal Goods Corp., was chairman, W. T. McClain, Shell Oil Co. and the University of Houston, spoke on the theoretical aspects of corrosion. He presented some examples of hydrogen embrittlement, hydrogen blistering and stress corrosion cracking. Mentioning some cases, he said often a cure could be found by increasing alloy content or by modifying the environment of the metal involved.

E. C. Winegartner, Humble Oil and Refining Co., found a simple solution to refinery corrosion encountered in high tensile stud bolts in floating heads of heat exchangers. Mr. Winegartner's advice was, "Don't tighten the head bolts too tight."

B. B. Morton, International Nickel Co., Inc., working on research and development in the petroleum and petrochemical industries, told his listeners that many metallurgical problems could be solved but the price is too high. Use of platinum as a non-corrosive material is prohibited because of cost, he cited as an example. However, reacting to pressure put on them by design engineers, metallurgists are developing better metals. Jack Rice, also of International Nickel Co., spoke about new alloys, cast irons and their uses, ductile irons, chrome-nickel and chrome-nickel-copper cast irons which are being developed.

Bob Clarkson, Mathieson Chemical Co., discussed problems encountered in chemical plants. High alloys are often used in making the machines and equipment which can withstand the corrosive atmospheres engendered by chemical processes, he said.

Philadelphia Section to Honor Past Chairmen

Five past chairmen of the Philadelphia Section will be honored at a May 14 meeting at the Poor Richard Club. Past chairmen invited to be present are Hugh H. Hamilton, 1949; Robert R. Pierce, 1950; Henry F. McConomy, 1951; W. Ronald Briggs, 1952 and Edward G. Brink, 1953.

Two technical discussions are scheduled also. James F. Madigan, Rohm and Haas Company, will speak on Electrochemical Series Corrosion and F. W. Ringer, consultant, will talk about Solution of Cathodic Protection Interference Problems.

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The Eleventh Annual Conference and Exhibition of NACE will be held in Chicago in March, 1955.

Huff to Assist NACE Sections and Regions

Robert Huff, for the past two years a member of NACE Central Office staff will assist in services given to regions and sections of the association as well as assist in office functions under a realignment of duties effective March 18 of members of the staff.

Mr. Huff is a graduate in chemical engineering from Texas A & M College.

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Requests for reprints of technical or other material published in CORROSION should be addressed to NACE's Central Office, 1061 M & M Bldg., Houston 2, Texas.

Southwestern Ohio Section To Nominate Officers

At the March 30 meeting of Southwestern Ohio Section at Shuller's Restaurant in Cincinnati, Arthur Caster, chairman, appointed a nominating committee to present a slate of officers for the local section for the coming year. This committee is comprised of Roy McDuffie, Clifford Jones, William Schreiner and David Jones.

The 23 members and guests heard Dr. Frank Beck of the Ohio State University present a talk on stress corrosion which was supplemented by a motion picture.

Increase in Membership Dues Approved by Board

Specialty Alloys Is Sabine-Teches Topic

"Specialty Alloys" was the topic of the technical talk presented to members of the Sabine-Neches Section at a March 25 dinner meeting held in Al's Seafood Cafe in Port Arthur, Texas. Frank Guba, Carpenter Steel Co., Union, N. J., was the speaker. He discussed the use of various types of alloys including Hastelloy, titanium and zirconium combinations. A spirited discussion period followed Mr. Guba's talk.

Section members will "forget business" for the May meeting and devote themselves to having a good time. C. A. Ridenour, section chairman, appointed a committee to arrange the meeting. Another committee was selected to nominate officers for the coming section year.

Technical subject scheduled for the April 29 meeting was "An Appraisal of Modern Type Paint Coatings," with E. M. Oswald, technical manager, Socony Paint Products Co., as the speaker.

Average Attendance Is High at Kansas City

Attendance figures for technical events during the Kansas City conference in March show that average attendance was higher than was reported for the 1953 meeting at Chicago. Especially noteworthy was the sustained high interest in the Educational Lectures at which attendance of 280, 350 and 350 was reported for the three lectures respectively.

Attendance at the general business meeting was from 100 to 300 at varying times compared to 75 reported at the 1953 meeting.

Lehigh Valley Section

It has been announced that the Lehigh Valley Section of the Northeast Region was formed as of March 15, 1954. S. C. Frye, Bethlehem Steel Company, Bethlehem, Pennsylvania was elected secretary-treasurer.

Conference Report Is Given at Rochester

The second meeting of the Genesee Valley Section was held on March 23 in the Rochester German Club. Dr. David Priest of the Pfaudler Company presented a brief report of the 10th Annual NACE Conference and Exhibition in Kansas City.

Following Dr. Priest's report John Adkin of the Rochester Gas and Electric Corporation presented some of his experiences in planning and installing cathodic protection for the gas distribution system in Rochester and the surrounding area. Mr. Adkin's presentation was followed by an enthusiastic discussion.

The Genesee Valley Section's next scheduled meeting is May 18 in the Pfaudler Company Research Laboratory, when Dr. Priest will show his film on stress corrosion cracking. This will be followed by a visit to the corrosion laboratory of the Pfaudler Company.

Reactor Materials

Materials of Construction for Reactors will be among the topics to be discussed at an International Engineering Congress to be held at the University of Michigan, Ann Arbor, Mich., June 20-25. Ninety papers will be presented on a number of subjects related to the peacetime uses of atomic energy.

Year's Extension of Corporate Members' Premiums Is Voted

An increase in annual dues of the National Association of Corrosion Engineers to $10 effective January 1, 1955 has been approved by the association's board of directors. This is the first increase in association dues since the organization was founded in 1945. The association's executive committee is scheduled to consider matters related to this increase at its next scheduled meeting, probably in July.

The board also made the following decisions at Kansas City:

Extended to March 11, 1955 the time during which sections that secure new corporate members for the association may receive a $25 premium for each new corporate member obtained.

A yearbook will be published in 1955 which will include, in addition to the usual rosters of membership and committees a classified industrial advertising directory.

A committee is scheduled to prepare certificates to be available by purchase from NACE, one for presentation to retiring sectional and regional officers and one for purchase by individual members to denote membership in NACE.

Topic of Month to Be In Technical Section

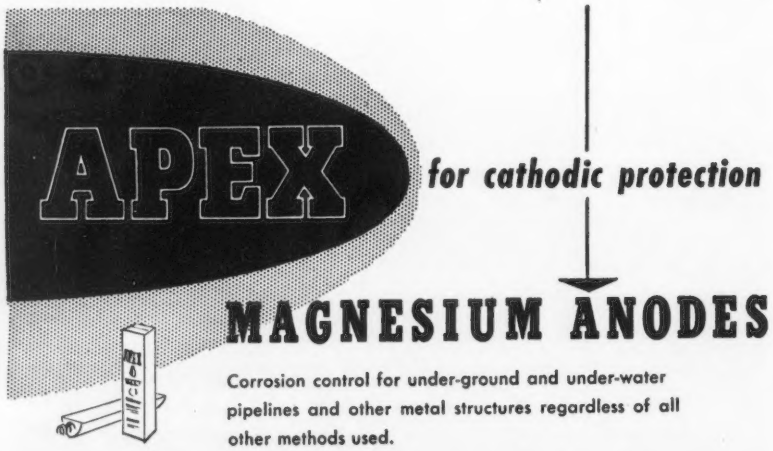
Effective with the July, 1954 issue of Corrosion the feature "Topic of the Month" which during the past five years has been located at the beginning of the News Section of the magazine, will be shifted to the first page of the Technical Section. This change is made as a consequence of the beginning of the section "Technical Committee News" scheduled to be a monthly part of the News Section.

Interest in the Topic of the Month last year necessitated indexing it with the technical section in the annual index.

Electrochemical Society Elects Hackerman

Norman Hackerman, professor of chemistry at University of Texas and director of the corrosion research laboratory there has been elected vice president of The Electrochemical Society. Dr. Hackerman, chairman of the NACE Education Committee and a member of the Abstract Committee as well as active otherwise in the association for many years, takes office May 4 during the society's 104th annual meeting.

A continuing high level demand for cast iron pressure pipe and fittings throughout 1954 is indicated by an analysis of trends prepared by the Business and Defense Services Administration, U. S. Dept. of Commerce. A rise in the per capita consumption of water is a reason given for the increased demand.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Technical Committee News

Formation of Local Technical Groups Favored

Officers Are Named for Technical Committees

H. W. Schmidt, Dow Chemical Company, chairman of NACE Technical Practices Committee, has announced the appointment of chairmen for the six Technical Group Committees provided for in the Technical Committee Operation Manual, which became effective on March 18, 1954.

E. C. Greco, United Gas Corp., Shreveport, Louisiana, was appointed chairman of Group Committee T-1, Corrosion in Oil and Gas Well Equipment.

W. H. Stewart, Sun Pipe Line Co., Sun Oil Co., Beaumont, Texas, was appointed chairman of Group Committee T-2, Pipe Line Corrosion.

F. M. Watkins, Sinclair Research Laboratories, Harvey, Illinois, was appointed chairman of Group Committee T-3, General.

F. E. Kulman, Consolidated Edison Co. of N. Y., Inc., New York, was appointed chairman of Group Committee T-4, Utilities.

Paul J. Gegner, Columbia-Southern Chemical Corp., Barberton, Ohio, was appointed chairman of Group Committee T-5, Corrosion Problems in the Process Industries.

A. J. Liebman, Pitmar Centrifugal Machine Corp., Pittsburgh, Pennsylvania, was appointed chairman of Group Committee T-6, Protective Coatings.

Long Active in NACE

These appointees have long been active in NACE committee work and Mr. Schmidt feels they are well qualified to coordinate the work carried on by the Unit Committees within their respective groups. These men, along with Mr. Schmidt, chairman; C. P. Larrabee, Research and Development Laboratory, United States Steel Corp., vice-chairman and F. L. Whitney, Jr., Monsanto Chemical Company, vice-president of NACE, comprise the Technical Practices Committee under the Technical Committee Operation Manual. The function of the Technical Practices Committee is to coordinate activities of all NACE Technical Committees. It is a policy and planning group which will establish procedures necessary for orderly business conduct of the committees, stimulate committee activity and aid in initiation of new committee activities.

Managing Group Named

A Managing Committee, working within the Technical Practices Committee, will act for the Technical Practices Committee, subject to approval of its actions by the committee. Mr. Schmidt, as Committee Chairman, Mr. Larrabee, as Committee vice-chairman, and Mr. Whitney, as Vice-President of NACE, presently comprise the Managing Committee.

First Appearance of New News Feature

This, the first appearance of the "Technical Committee News" section of Corrosion magazine, is an effort to present in news story form some of the activities of the technical committees of the National Association of Corrosion Engineers. The expanding work of these groups is developing much timely material which is of interest and value to NACE members and others not members of the committees.

The material in this section is prepared under the direction of the Technical Committee Secretary with cooperation of the personnel of the committees. Members of the association's technical organizations are urged to make use of this section.

T. J. Hull Is Named Committee Secretary

Tennyson J. Hull, an employee at Central Office, Houston has been assigned the duty of acting as secretary for the NACE Technical Committees, following authorization by the association's board of directors at the Kansas City conference in March. Mr. Hull will assist in coordinating the work of the technical committees to avoid duplication of effort and in the preparation, reproduction and distribution of technical reports. He also will provide the information for what is expected to be a new monthly department of Corrosion magazine, Technical Committee News, the first appearance of which is in the May issue.

Mr. Hull, a graduate in mechanical engineering from the University of Houston, has been with NACE Central Office for two years.

In-Line Tests of Coupons Are Scheduled

Three members of T-2E-1 on Internal Corrosion of Product Pipe Lines and Tanks have agreed to run triplicate in-line tests of proposed coupons in their companies' pipe lines. The tests are to be made to determine the degree of reproducibility that may be expected. A progress report on laboratory tests of the proposed standard test coupons indicated that the tests were not satisfactory, according to Ivy M. Parker, Plantation Pipe Line Co., Atlanta, chairman.

The group also discussed briefly methods of determining and the significance of the C factor, filter paper tests as indication of quality and the effect of mixing inhibitors.

Opportunity Seen For Participation By More Members

NACE sections and regions are urged to form technical groups to function under the association's expanded program for corrosion investigations. H. W. Schmidt, chairman of the NACE Technical Practices Committee, speaking to the association's regional management committee during the March conference at Kansas City, pointed out that many localities have problems peculiar to them which can be solved best by local groups. This will make it possible for many NACE members now barred from participation in technical committee work because they are unable to attend national and regional meetings to get real benefits from the cooperation opportunities the association provides, he said.

Mr. Schmidt cited the work being done by existing regional committees as indicative of what can be expected from such groups. T-1K-1 on Inhibitors for Oil and Gas Wells, Mr. Schmidt said, along with T-6L-1 on Asphalt Type Coatings, T-1L-1 on Waste Water Disposal and T-6M on Field Coating Inspection, all of Pacific Coast Region and T-5C-1 on Corrosion by Cooling Waters—South Central Region show the kind of activity he has in mind. These committees, he pointed out, have been and are now active studying problems in their respective regions.

Receive Current Information

Committees working at section or region levels would receive current information on corrosion investigations on the national level which is significant to them, Mr. Schmidt said. This would help avoid duplicated effort and give the national committees the benefit of the local groups' work as well, he said.

Mr. Schmidt invited inquiries concerning procedures from any group interested in setting up a local technical committee. Information can be obtained from H. W. Schmidt, The Dow Chemical Company, Midland, Mich., or from T. J. Hull, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

New Plastics Committee

NACE members interested in the subject of plastic materials of construction and who would like to work on a committee are invited to communicate with Raymond B. Seymour, Atlas Mineral Products Co., Mertztown, Pa. who has been named chairman of a new group on this topic. The unit committee, to be organized under T-5 on Corrosion Problems in the Process Industries, will be designated T-5D.

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Scope, Organization and Objectives of High Purity Water Committee Are Given

More High Temperature Data to Be Collected

Uptodate information on corrosion in ammonia and liquid metals and the corrosion resistant characteristics of acid brick and cement is to be added to a report being prepared for publication by T-5B on High Temperature Corrosion. The committee's "Tables Containing Corrosion Data at Temperatures Above 400 Degrees F," a report expected to be submitted for publication after some minor revisions including the additions listed, was discussed at Kansas City in March, M. A. Scheil, A. O. Smith Corp., Milwaukee, reported. T-6K is expected to supply the data on acid resisting brick and cement.

The committee's discusssion centered around high temperature corrosion testing procedures involving materials subjected to changing environments. This subject was considered sufficiently important to justify setting up a task group under T-5B to be designated T-5B-1. E. N. Skinner, The International Nickel Co., Inc., New York, accepted chairmanship of the group. The assignment is to initiate a program of exposure tests in cases where further information is desirable. A limited number of cataloged stainless steel and nickel alloy discs have been made available to the group for testing by The International Nickel Co.

John J. Halbig, Armco Steel Corp., Middletown, Ohio was elected to succeed Mr. Scheil as committee chairman. A vice-chairman will be elected.

Bibliography on Snow Removal Methods Set

TP-19 Corrosion by Deicing Salts, now T-4D decided at a meeting held during the recent conference to issue a bibliography of snow removal references. The committee also plans to form task groups whose assignment will be to specify methods for field testing on automobiles and to coordinate the efforts of municipalities, salt and inhibitor manufacturers and motor vehicle operators in conducting and interpreting future field tests.

M. B. Hart, Illinois Bell Telephone Co., Chicago, Illinois, chairman of T-4B reported that a growing interest in corrosion by deicing salts was evident in the active discussion at the Kansas City Meeting of TP-19. A progress report of the committee's activities published in the January, 1954, issue of CORROSION indicated the economic loss on automobiles and subsurface pipes and cables that could be traced to corrosion caused by salts and made clear the need for further activity on the part of T-4B.

ASHVE Will Meet

The American Society of Heating and Ventilating Engineers will hold its 60th semi-annual meeting at Swampscott, Mass., June 28-30, 1954.

F. M. Watkins, Sinclair Research Laboratories, Inc., and chairman of NACE Technical Committee T-3, General, has announced the formation of a new unit committee to work on corrosion by high purity water problems. The new committee is designated T-3F Corrosion by High Purity Water.

The committee held its first meeting in Kansas City during the recent conference. D. J. DePaul, Atomic Power Division, Apparatus Subdivision, Westinghouse Electric Corporation was appointed chairman and J. F. Eckel, General Electric Company was elected vice-chairman. Mr. DePaul and Mr. Eckel will serve for two years.

The scope of the committee adopted at the meeting is "To provide for the accumulation, correlation and dissemination of all pertinent information which has been developed concerning the corrosion resistance of materials in high purity water." Mr. DePaul said members of the committee affiliated with Argonne National Laboratories, Babcock and Wilcox Company, Westinghouse Corporation and General Electric Company have been actively connected with problems involving corrosion by high purity water, and observed that the background of the members making up the original membership of the committee is such that a smoothly operating group should result.

Mr. DePaul also outlined in detail a number of objectives he felt the committee should pursue. To reach these objectives the committee was divided into three groups:

Group 1. The function of this group shall be to lay the ground work for the preparation of a Bibliography on Corrosion by High Purity Water, to issue a general report and to issue specific reports.

Group 2. This group is to be concerned with organizing a symposium which it is hoped can be presented at the next NACE Annual Conference.

Group 3. The function of this group is to establish a link between work done especially at Atomic Energy Commission installations and industry in general. This group also will serve to interpret data in terms of its usefulness to industrial applications apart from reactor technology.

Mr. DePaul said that only unclassified information will be discussed in the work of the committee.

The committee, in the discussion during the meeting, felt that at least three papers could be obtained readily for a symposium on the following general subjects: 1. Basic Fundamentals; 2. Application Problems, and 3. Link to Industrial Applications.

Plastics Exposition

The National Plastics Exposition, sponsored by the Society of the Plastics Industry, Inc., will be held June 7-10, 1954 in the Cleveland, Ohio Public Auditorium. Four industries will take part in the program. Radio and television set makers, rubber industry, refrigeration and air conditioning manufacturers and automobile producers.

Effect of Phosphoric Acid on Adhesion Of Linings Debated

Use of phosphoric acid in preparing tank car surfaces for lining should be optional in the opinion of T-3E-1 on Corrosion of Railroad Tank Cars. The committee, at a meeting in Kansas City during the Tenth Annual Conference and Exhibition agreed that phosphoric acid may change the surface of the steel and thus affect the adhesion of the coating. Experience of one member indicated phosphoric acid considerably reduced adhesion and induced early failure. The committee also is seeking a standard by which to judge the degree of curing of a baked coating.

Consideration was given also to a recommendation that pre-baking temperature should be specified and that coating procedure be expanded to include removal and disassembly of relief valves and individual coating of their pieces, providing means are available for resetting the valve. The outlet valve may or may not require removal depending on the type of service expected of the car.

The committee is interested also in a more reliable method of judging the degree of cure of a baked coating. Currently baking is judged by visual examination of the color of the coating or by wiping it with a solvent saturated rag to determine whether any solution occurs. It was pointed out that a coating may pass the wiping test and still be insufficiently cured to give maximum service life.

Field data sheets and a summary prepared by the committee were discussed. Most members, especially tank car users, indicated the information was valuable to them. However, the committee believes the information would be more useful if it were given in greater detail and expanded into a record of field experience. Manufacturers of coatings, steel and alloys will be asked for their experience.

The discussion on cleaning practices, another project of the group, centered around recommendations that residual commodity be removed before cleaning and that steam pressure be stipulated. A chart being compiled on cleaning practice will be expanded to list coatings generically by type, and cleaning compounds commonly used which are considered alkalies. It also was recommended that neutral sulfonated petroleum detergent be added to the cleaning compounds list.

Standard for Screening Inhibitors Planned

A tentative standard method of screening materials for use as corrosion inhibitors for use in oil and gas wells will be prepared by T-1K on Inhibitors for Oil and Gas Wells. J. C. Spalding, Jr., Sun Oil Co., Dallas, chairman of the committee said a meeting will be held in May or June to write the standard.

Preliminary reports of results of testing inhibitors made by committee members were discussed during the recent meeting of the group in Kansas City.

Long Term Tests Favored For Structural Plastics

Strength tests of structural plastic materials should include long-term tests under temperatures and chemical environments existing in oil field installations it was agreed by two members of T-1J at the Kansas City meeting of the group. The committee also heard a summary of results of a questionnaire covering 73 plastic pipe installations of more than 110,000 feet of 1½ to 5-inch, extruded plastic pipe. Although failures were reported most of the pipe is giving satisfactory service.

F. A. Prange, Phillips Petroleum Co. and R. S. Treseder, Shell Development Company, who presented reports on test methods employed by their respective companies, favored field tests of plastic pipe.

The committee is continuing its effort to accumulate engineering data on oil field structural plastics, W. M. Thornton, Atlantic Refining Company, chairman reported. Intelligent, economic use of the materials in the oil producing industry is the committee's aim.

At the next meeting of the group reports are expected on field service experience with glass-reinforced plastic pipe, tubing and tank materials. Laboratory testing techniques and results will also be discussed further.

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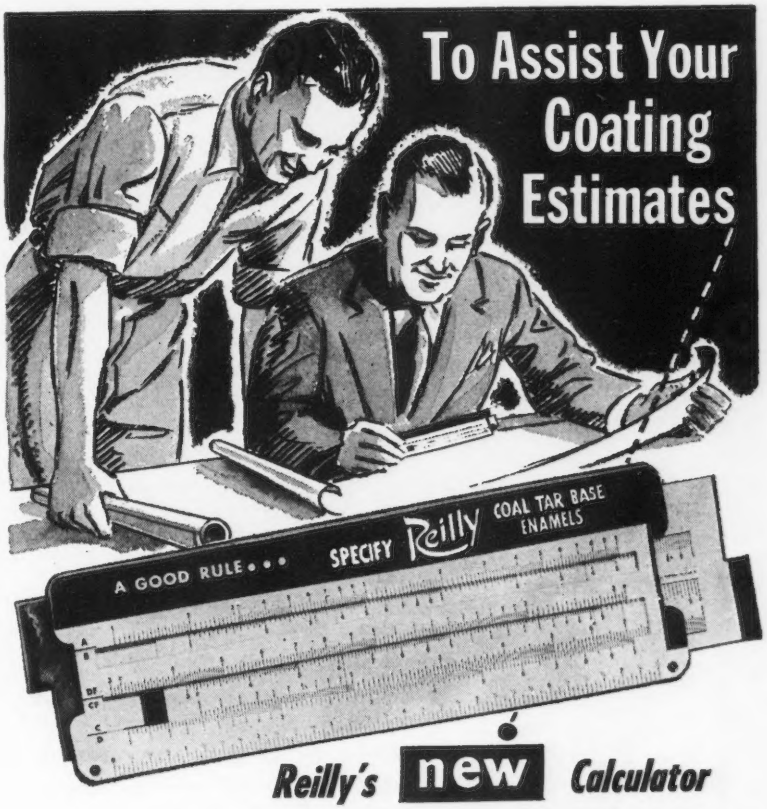
Articles on meetings pertaining to corrosion control held anywhere in the world are welcomed for publication in CORROSION, NACE official monthly magazine.



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Book on Corrosion of Oil and Gas Well Equipment Started

Work has begun on a book to be devoted to corrosion of oil and gas well equipment. The book, which will be compiled under the direction of NACE T-1 on Corrosion of Oil and Gas Well Equipment, was suggested by the American Petroleum Institute. A temporary committee was named at Kansas City to begin work on the project, and to make recommendations to the American Petroleum Institute on revisions to the corrosion-connected subject matter of the "API Recommended Practice for Care and Use of Casing, Drill Pipe and Tubing."

E. C. Greco, United Gas Company, Shreveport is now chairman of T-1, succeeded R. C. Buchan, Humble Oil and Refining Co., Houston.

Subcommittees Report

The following subcommittee reports of the old TP-1 committee were given at Kansas City during an all day meeting of the group:

TP-1A (now T-1K-1 and T-1L-1). Frank Davie, Shell Oil Co., Los Angeles reported on corrosion of oil and gas well equipment on the Pacific Coast.

TP-1B (now T-1B) R. C. Buchan, Humble Oil and Refining Co., Houston reported on condensate well corrosion.

TP-1C (now T-1C) H. E. Greenwell, Atlantic Refining Co., Dallas reported on sweet oil well corrosion.

TP-1D (now T-1D) J. A. Caldwell, Humble Oil and Refining Co., Houston reported on sour oil well corrosion.

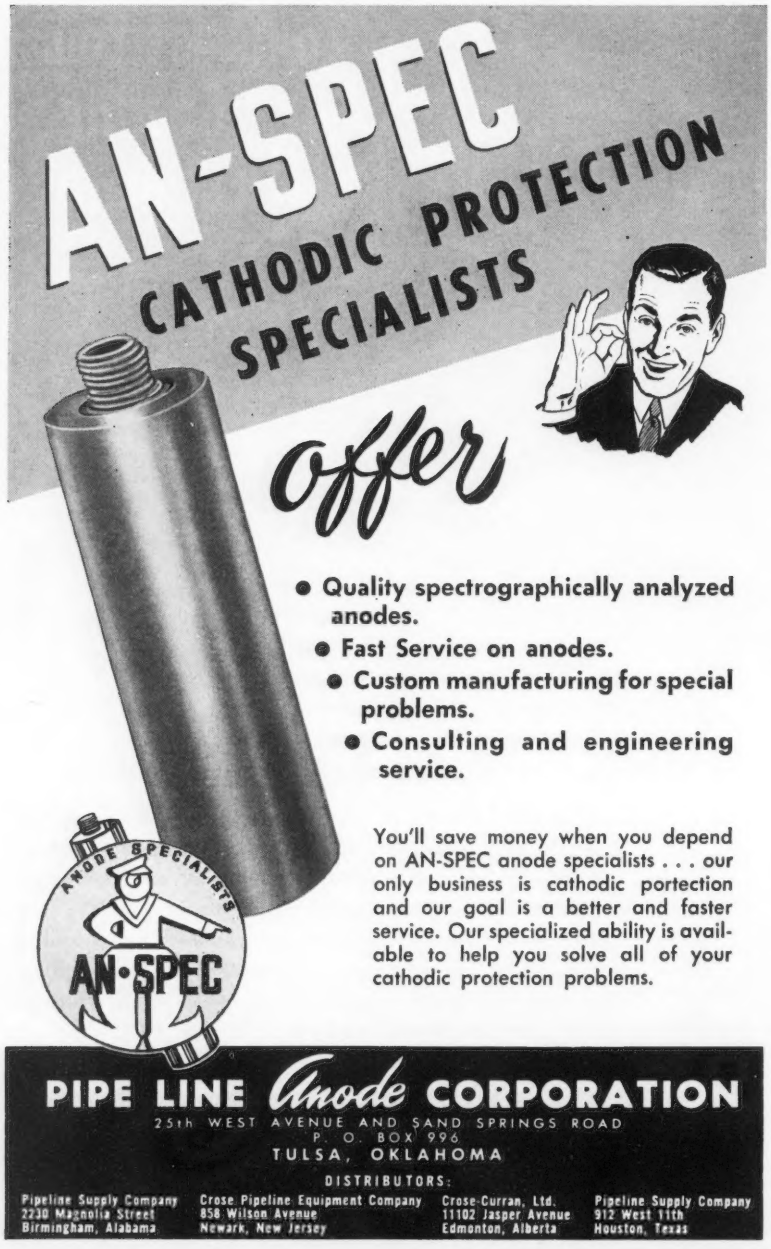
TP-1F (now T-1F) F. A. Prange, Phillips Petroleum Co., Bartlesville, Oklahoma reported on metallurgy—oil and gas well equipment.

TP-1G (now T-1G) R. S. Treseder, Shell Development Co., Emeryville, Cal. reported on sulfide corrosion cracking.

TP-1H (now T-1H) Jack L. Battle, Humble Oil and Refining Co., Houston reported on corrosion of oil string casing.

TP-1J (now T-1J) B. W. Bradley, Shell Oil Co., New York, N. Y. reported on oil field structural plastics.

TP-1K (now T-1K) J. C. Spalding, Jr., Sun Oil Co., Dallas reported on evaluation of inhibitor testing methods.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Catalog of Types of Lead Sheath Corrosion Is Aim of T-4B-1

Identification and classification of specimens of the types of corrosion affecting lead sheath cables will be a function of T-4B-1 on Corrosion of Lead and Other Metallic Sheaths. The decision was reached by the committee at its meeting at Kansas City when reports of four groups in the cable corrosion field were heard.

T. J. Maitland, American Telephone and Telegraph Company, chairman of T-4B-1 reported on committee activities. V. B. Pike, Bell Telephone Laboratories, told of information gathered by his group on concentration cells; W. S. Woodward, New York Telephone Company, reported on alternating current corrosion and instances of corrosion which may have been caused by alternating current and Mr. Maitland gave some information on microbiological action.

New Correspondent for Light Metals Is Named

Fred M. Reinhart, who is with the National Bureau of Standards, Washington, D. C. has accepted a 3-year appointment as correspondent to Corrosion on Light Metals. He succeeds R. H. Brown, Aluminum Company of America, New Kensington, Pa. Correspondents to Corrosion are asked to supply once a year for the feature "Topic of the Month" an article in the field of their assignment.

Electrochemical Society

Among the papers with corrosion-connected subject matter scheduled for presentation at the 104th Annual Meeting of The Electrochemical Society at Chicago May 2-6 are:

Pyrosol Formation and Corrosion of Titanium in Fused Salts by C. B. Gill, M. E. Straumanis and A. W. Schlechten, Dept. of Metallurgical Engineering, University of Missouri School of Mines and Metallurgy, Rolla.

Radio Tracer Studies of Electrolytic Action on Metal Surfaces by Massoud T. Simnad, Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh.

Armour Foundation's Corrosion Research Is Wide in Scope

Extensive investigations into corrosion are under way at Armour Research Foundation of the Illinois Institute of Technology, Chicago. A canvass of the annual report indicates both practical and theoretical research is in progress and that some discoveries of real importance have been made.

Among the research activities reported which involve corrosion were:

Electrochemistry—Further investigations of the rotogenerative technique to measure the electrostatic field associated with corrosion are under way. High temperature x-ray diffraction studies of ceramic materials were carried on and the foundation has contributed six articles to a forthcoming monograph on high temperature materials which will be published by The Electrochemical Society.

Refractory Coatings—A new method of applying refractory coatings to glass, metals and other materials has been discovered. Among the anticipated uses for the new process are protection against molten metals, oxidation and corrosion by a variety of metals and alloys including molybdenum, tungsten and steels.

Enamelware—It was learned that adequate enamel adherence can be obtained to steel following preparation of the surface by light sandblasting.

Inhibitors—Investigations into the possibility new additives may be found for slushing oils which will have inhibitive effect equal to or better than sulfonates are underway. Relationship between structure and efficiency of the several inhibitors being tested also is being probed.

Stainless Steel Cookware—Resistance to corrosion by foods of stainless steel cookware used in the so-called waterless cooking method is being evaluated.

Deterioration of Fine Instruments—Factors contributing to deterioration of fine instruments in storage, including properties of horological lubricants, packaging, manufacture, assembly and handling. Bimetallic corrosion studies led to specific recommendations to avoid metal couples which create galvanic currents.

Plasticizers for Vinyls—Evaluation of plasticizers for vinyl resins developed by the Northern Regional Laboratories of the U. S. Dept. of Agriculture is underway.

Gear Lubricant Moisture—The degree of protection from corrosion imparted to stored differential gears by various gear lubricants is being probed. A test procedure which will permit evaluation of lubricants in combating corrosion also is being sought.

Diesel Engine Lubrication—Fundamental data on parameters and studies of methods of rating engine wear, cleanliness, corrosion and mechanical conditions are being sought.

Vanadium Base Alloys—The third year of investigations into the uses of vanadium base alloys is under way. Experimental results outstanding for wrought materials have been obtained at temperatures up to 900 degrees C. Four superior ternary systems are under test to determine creep-rupture properties.

Phase Relationships in Magnesium-Lithium-Aluminum Alloys—Reasons for the unsuppressible embrittling aging of these alloys at room or slightly elevated temperatures are being sought.

Plating Waveguides—Electrodeposited high conductivity silver coatings on the insides of waveguides using the periodic reverse technique are being tested.

Stress Corrosion of Aircraft Alloys—The investigation into stress corrosion behavior of aircraft alloys is in its third year.

Electroplating on Titanium—Considerable success in plating other metals on titanium has been achieved.

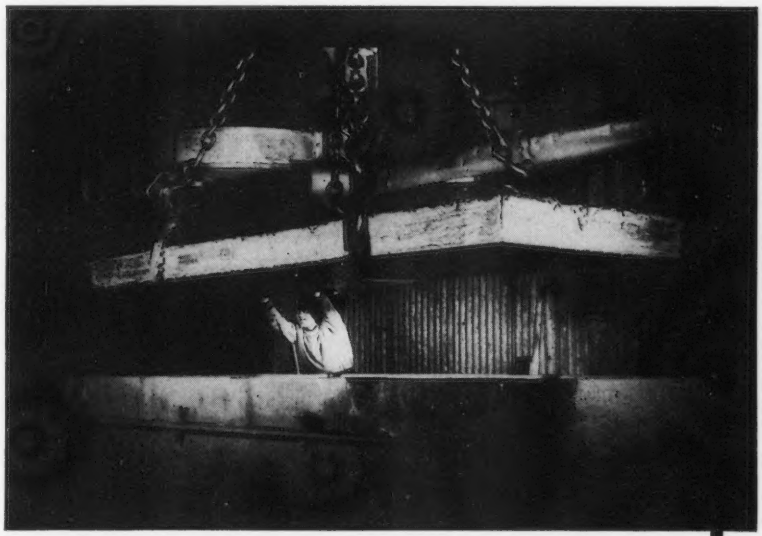
Tin Plate Corrosion—The twelfth year of investigations of the influence of the steel base on corrosion resistance of tin plate has begun.

Paper Mill Corrosion—A fundamental study of corrosion inhibitors for use in paper stock solutions is in progress.

Titanium and Alloys—Further investigations into the corrosion resistance characteristics of titanium at high temperatures, titanium-aluminum binary alloys, 36% aluminum titanium-base alloy and promising elevated temperature titanium alloys are under way.

Welding—Studies in welding processes include recrystallization welding of aluminum aircraft alloys, effects of alloying elements on weldability of titanium sheet, gas absorption in arc weld metal and welding of steam piping.

Elevated Temperature Properties—Physical properties of certain metals at elevated temperatures are being examined in a program now in its fourth year. They include titanium and some titanium alloys, several stainless steels, a number of aluminum alloys and a nickel-chrome-molybdenum alloy, all tested at temperatures from room to 1200 degrees F.



Subject: lead sheet and pipe

You may say that lead pipe and lead sheet are pretty much alike no matter who makes them or from whom you buy them. "Pretty much alike" is right. But not exactly alike. Here's why . . .

Federated's experience in lead production and in lead research means that you profit two ways when you buy corrosion-resisting lead pipe, sheet, valves or fittings from Federated: You get a product that is *certain* to be as good as any other . . . and probably better . . . *and* you get the *best technical help* with your problem.

For any information on the use of lead, write to Federated's *Corrosion Advisory Service*. Address the main office (below) or any one of Federated's 14 plants and 24 sales offices across the nation.

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Gordon Conference Is Scheduled July 19-22

The July 19-22 Gordon Research Conference on Corrosion to be held at Colby Junior College, New London, N. H. will have Aaron Wachter, Shell Development Company, Emeryville, Cal., as chairman. Dr. Wachter is president of the National Association of Corrosion Engineers. Vice-chairman will be E. A. Gulbransen, Westinghouse Electric Corp. Mr. Gulbransen received the NACE 1952 Willis Rodney Whitney Award for achievement in corrosion science.

Applications for attendance should be sent to W. George Parks, Director, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island before May 15. Attendance is limited to 100.

The program has been given as follows:

July 19—A. C. Zettlemoyer, Heterogeneity of Surfaces; C. V. King, Adsorption of Metal Salts on Metals; Norman Hackerman, Molecular Structure, Metal Character and Inhibition; Rudolph Speiser, Passivation of Several Metals and N. Hackerman, Some Experiments in Passivity of Metals.

July 20—M. J. Pryor, An Interpretation of the Significance of the Passive Potentials on Steel; Morris Cohen, Electrochemical and Surface Studies on Iron in Inhibitor Solutions; C. V. King, Corrosion Inhibition in Acid Solutions; H. C. Gatos, Corrosion Inhibitors and Polarographic Maxima; Morris Cohen, Initial Consumption of Inhibitors on Iron; E. J. Schwoegler, Functional Groups in Organic Inhibitors.

July 21—J. J. Harwood, chairman, Hydrogen in Metals. J. J. Harwood, Effects of Hydrogen on Mechanical Properties of Metals; L. D. McGraw, Mechanism of Hydrogen Entry into Metals During Corrosion Processes; W. R. Heller, Occlusion of Hydrogen in Metals during Corrosion Processes; M. C. Bloom, Some Relations Between Hydrogen and the Corrosion Behavior of Metals; J. J. Harwood, Sulfide Corrosion Cracking; W. D. Robertson, Mechanism of Sulfide Corrosion Cracking of Steels; Aaron Wachter, Cracking of Steels in Aqueous Hydrogen Sulfide; H. H. Uhlig, Cracking of Ferritic Stainless Steels as Related to Hydrogen Absorption Resulting from Corrosion.

July 22—E. A. Gulbransen, chairman, Corrosion at High Temperature. Carl Wagner, Solved and Unsolved Problems in High Temperature Oxidation; Manley W. Mallet, Oxidation of Zirconium and Zirconium-Tin Alloys; Allen T. Gwathmey, Rates of Formation of Oxide Films on Iron Single Crystals.

Quality Control Society

The American Society for Quality Control will hold its eighth annual convention in St. Louis, Mo., June 9-11, 1954. Headquarters will be in the Jefferson Hotel with technical sessions at Kiel Auditorium. The program will consist of 72 sessions, 67 technical sessions and 5 sessions devoted to plant tours. Registration blanks and further information may be obtained from: U. C. Gramsch, Registrar, 8th Annual ASQC Convention, P. O. Box 4436, Wade Station, St. Louis 15, Mo.

1955 NACE Officers, Directors Nominated

The following have been named by the NACE nominating committee for election as officers and directors during 1955:

For president: F. L. Whitney, Jr., Monsanto Chemical Company, St. Louis.

For vice-president: W. F. Fair, Jr., Koppers Company, Inc., Tar Products Division, Westfield, N. J.

For treasurer: R. A. Brannon, Humble Pipe Line Company, Houston.

For director, representing active membership: W. H. Stewart, Sun Pipe Line Co., Beaumont, Texas.

For directors, representing corporate members: Robert R. Pierce, Pennsylvania Salt Manufacturing Co., Philadelphia; C. G. Munger, Amercoat Corp., South Gate, Cal.

Electrotechnical Group To Meet September 1-16

The International Electrotechnical Commission will hold its fiftieth anniversary meeting on the campus of the University of Pennsylvania, September 1-16. It is anticipated that 700 electrical technical experts from 29 countries and the U. S. will attend. Delegates will work on international standards in the fields of electric light, power and communications.

Purpose of the organization is to work to provide engineers of all nations a common nomenclature through unification of terms and by publishing an international vocabulary in several languages. The other principal objective is the preparation of standards for electrical machinery and apparatus.

Polymeric Materials Symposium Scheduled

A symposium on Polymeric Materials of Construction will be given beginning at 2 pm, May 18 during the Springfield, Mass. National Meeting of the American Institute of Chemical Engineers at Hotel Kimball. Papers scheduled during the symposium are:

Vulcanizable Elastomers as Materials of Construction by B. M. G. Zwicker, B. F. Goodrich Chemical Co., Cleveland. Thermosetting Resins Reviewed for the Chemical Engineer by R. J. Schatz and S. H. Rider, Monsanto Chemical Company, Springfield, Mass.

Vinyl Plastics as Materials of Construction by Raymond B. Seymour, Atlas Mineral Products Co., Mertztown, Pa.

Properties of Polyethylene, Polytetrafluoroethylene, Polymonochlorotrifluoroethylene Acrylic Resins and Cellulosics by J. J. Ondrejcin, E. I. du Pont de Nemours and Co., Wilmington, Del.

New Use for Steel Waste

A new four-step method of producing fertilizer, steel and critically short manganese from waste material of the steel industry was described at the March national meeting of the American Institute of Chemical Engineers.

ASME Committee on Boiler Feedwater Gets Adams as Chairman

Robert C. Adams, superintendent of the Chemical Engineering Laboratory at the U. S. Naval Engineering Experiment Station at Annapolis, Md., has been appointed chairman of the Joint Research Committee on Boiler Feedwater Studies sponsored by the American Society of Mechanical Engineers. He replaces Everett P. Partridge who retired after being chairman two years.

The committee has three subcommittees actively engaged in problems on corrosion, deposits and steam contamination. One corrosion project is the investigation of the basic corrosive reactions of water on steel under conditions of high pressure boiler operation. The project calls for the determination of: 1. The solubility product of $FeO\text{-}H_2O$ at 70 to 600 degrees F to establish the equilibrium pH and ferrous ion concentration. 2. The mechanism and rate of decomposition of $FeO\text{-}H_2O$ in pure water and in water of various pH values up to 12, over a temperature range from 70 to 600 degrees F.

Paralleling this work will be an engineering study to measure the rate of corrosion of low carbon steel: 1) In pure water as a function of heat transfer rates from 10,000 to 200,000 Btu per hr. per sq. ft. as a function of mass velocities within and exceeding the nominal range of furnace wall circuits in high pressure boilers and as a function of temperatures between 300 and 700 degrees F. 2) In water containing sodium hydroxide to give pH value up to 13 over the above range of variables. 3) In water containing typical salts, such as phosphate, sulfate and chloride over the above range of variables.

The society also has published a bibliography compiled from books and periodicals of several countries. It contains information on contaminants in steam and how to determine them, the mechanical and chemical factors contributing to steam contamination, such as deposits, corrosion, plant operation and corrective measures. Use of volatile inhibitors for preventing condensate system corrosion is included.

Civil Engineers Organize Pipe Line Committee

A committee on pipe lines has been established in the construction division of the American Society of Civil Engineers. The committee's purpose is to advance and correlate scientific knowledge, promote and coordinate economic development and construction of engineering projects involving transmission of fluids, gases and solids by pipe lines as it pertains to civil engineering, especially in the fields of surveying, line location, design, construction and operation.

The committee also will seek to promote use of established pressure piping codes among pipe line, highway, and railroad groups and public authorities.

NACE members interested in the committee may write to American Society of Civil Engineers, 33 West 39th St., New York 18, N. Y.

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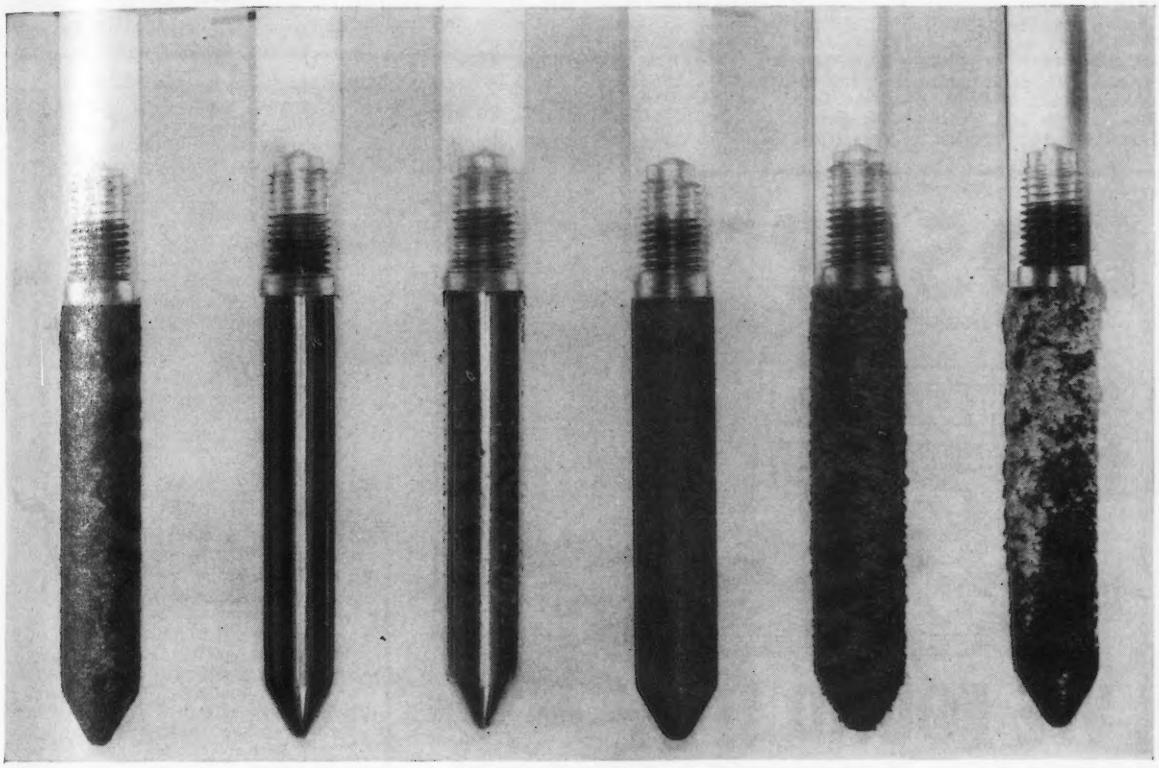

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The test pieces shown above were submerged for 48 hours in a dynamic system of sea water and oil. In each case the oil contained a different, well-known corrosion inhibitor.

The test specimen exposed to the mixture inhibited with Unicor was the only one to remain as bright and unpitted as a freshly prepared, unexposed test piece. All of the other inhibitors permitted varying degrees of corrosive attack.

These results were obtained by using the procedure of ASTM D 665-53T — the generally accepted method for determining the corrosion-preventing characteristics of inhibited hydrocarbon oils.

The specific conditions involved exposure to the action of synthetic sea water, air and sour catalytic cycle stock at a temperature of 140° F. for 48 hours.

Similar results were obtained with gasoline and other distillates by using this and other types of tests, including the Navy Static Water Drop Test.

In the field as well as in the laboratory Unicor has proved to be the ideal, economical corrosion inhibitor.

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BOOK REVIEWS

Pipe Line Corrosion and Cathodic Protection, A Field Manual. By Marshall E. Parker. 5 x 7¾ inches, 104 pages. Hard-backed, illustrated. Gulf Publishing Co., P. O. Box 2608, Houston, Texas. Per copy, $3.00.

The manual, according to the author, is the summation of much of the corrosion knowledge developed by many experienced corrosion engineers in addition to his own experience. The book is divided into 12 parts and an appendix.

Part 1, Soil Resistivity, deals with various methods of determining soil resistivity, locating "hot spots" on bare lines, surveys for ground beds and area surveys. Part 2, Potential Surveys, treats with pipe-to-soil potentials, electrode placement, surface potential survey for corrosion, the criterion of cathodic protection and other applications of pipe-to-soil potentials.

Part 3, Line Currents, considers measurement of line currents in test sections, stray current studies, cathodic protection tests and coating conductance measurement. Part 4, Current Requirement Surveys, deals with the determining of requirements for coated lines. Part 5, Rectifier Systems for Coated Lines, takes up rectifiers, their design and use. Part 6, Ground Bed Design and Installation compares by text and graphs, costs of various ground beds. Magnesium Anodes on Coated Lines is discussed in Part 7, including when and where to use magnesium anodes and how to install them. Part 8, Hot Spot Protection, describes methods of locating areas of high corrosive attack and how to deal with them.

Part 9 is titled Stray Current Electrolysis. Part 10, Interference in Cathodic Protection states the problem and gives some solutions. Part 11, Operation and Maintenance, gives sources of trouble after corrosion protective systems are installed and outlines some maintenance methods. Part 12, Coating Inspection and Testing, the last chapter of the book, gives methods of testing coatings before the coated material is put in use and how to test in-place installations.

Proceedings of the Short Course in Corrosion Held at the University of California. 8½ x 11 inches, 119 pages, paper backed, plastic binding. Dept. Conferences and Special Activities, University Extension, University of California, Berkeley 4, Calif. Per copy, $5.00.

A collection of papers presented at the University of California Short Course on Corrosion at Berkeley, February 2-6, 1953. Included in the book are discussions on fundamentals of corrosion, stress corrosion, corrosion of ferrous and non-ferrous metals, various coatings, corrosion in the process industry and in public water systems, cathodic protection principles and practices, corrosion study and testing including use of radiotracer techniques and high temperature corrosion.

Symposium on Porcelain Enamels and Ceramic Coatings as Engineering Materials. 9 x 6 inches, 122 pages, 1953. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy, $2.50.

Among the many technical papers printed are some on corrosion resistance of ceramic coatings. Some Examples of the Functional Use of Porcelain Enamel and Ceramic Coatings by G. H. Spencer-Strong explains the various enamels and their corrosion resistance to various environments. The paper Resistance of Porcelain Enamels to Weathering, by Dwight G. Moore, relates the results of test panels exposed for seven years by the National Bureau of Standards in four locations. Data and information on the corrosion resistance of glass fused to steel is given in a paper, "The Chemical Resistance of Glass Fused to Steel by E. A. Sanford and O. J. Britton. Exposure to hydrochloric acid, nitric acid, sulfuric acid and phosphoric acid at temperatures above 212°F, and specific instances where glassed steel is being used in severe services are cited. The acid resistance of porcelains is also considered in another paper, Acid Resisting Properties of Porcelain Enamels, by Harold C. Wilson.

Other papers tell of the abrasion resistance of porcelain and use of the material in high temperature jet engines.

Performance of Stainless Steels in Petroleum Refinery Service. 8½ x 11 inches, 44 pages, paper. 1953. United States Steel, 525 William Penn Place, Pittsburgh 30, Pa. Free.

Because of the combined effects of obsolescence, high temperatures, pressures and highly corrosive agents used it is

(Continued on Page 16)

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IT IS DOWN IN TEXAS!
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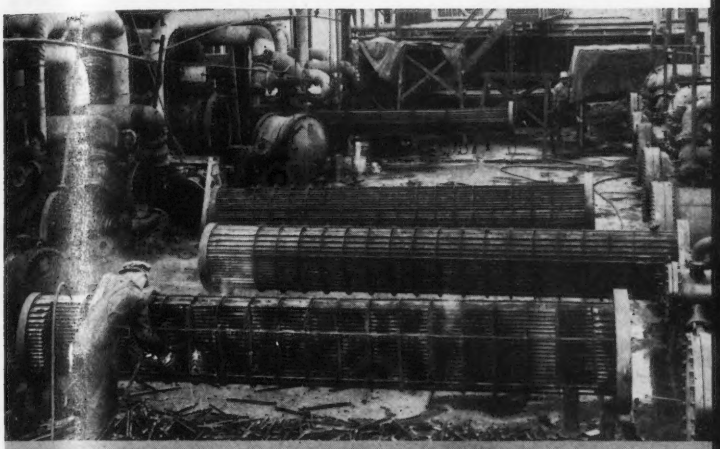

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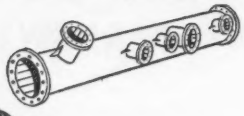

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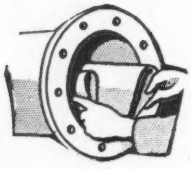

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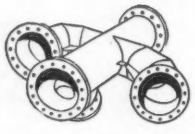
Affords maximum resistance to abrasion, and to corrosive oils, greases, solvents, bleaching liquors, fats, acids and other chemicals and aromatics. All Saran rubber linings are carefully applied by hand and are rigidly inspected by trained personnel and by electric spark testing devices.



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BOOK REVIEWS

(Continued From Page 14)

estimated present day refinery equipment must be replaced every five years at a cost of about 8 cents per days per barrel of capacity. This pamphlet collects for a large number of sources corrosion data based on actual refinery experience. The subjects covered in the booklet, which is in color, fully illustrated, with many tables and graphs include: General corrosion, which covers atmospheric, wet chemical and elevated temperatures; Intergranular corrosion which covers, carbide precipitation, attack by molten metals and sulfur attack.

Strength information is divided into short-time tensile, long-time creep and rupture properties; properties at atmospheric temperatures after exposure at elevated temperatures.

Condensate Well Corrosion. 6x9 inches, 203 pages, cloth. 1953. Natural Gasoline Association of America, 422 Kennedy Bldg., Tulsa, Okla. Per Copy, $6.00.

There are eighteen chapters each relating to the problems incident to corrosion in gas condensate wells. The work represents the accumulated data of 10 years' investigations by the Natural Gasoline Association of America's Condensate Well Corrosion Committee. In addition there is presented much useful information of economic nature, experimental procedure, laboratory vs. field experience correlation, ratings of the efficiencies of various systems of control and numerous case histories which enable the corrosion engineer faced with a condensate corrosion problem to compare others' experience with his own case.

The chapter headings, which are sufficiently explicit to indicate content are as follows: History of Gas Condensate Well Corrosion Committee by W. F. Lowe, Natural Gasoline Association of America; Economics of Gas Condensate Well Corrosion by T. S. Zajac, Shell Oil Company, New York; Criteria of Corrosiveness, H. L. Bilhartz and H. E. Greenwell, The Atlantic Refining Co., Dallas; Chromate Inhibitors, Jerry R. Marshall, The Texas Company, Houston; Organic Inhibitors, H. E. Waldrip, Gulf Oil Corp., Houston; Neutralization-Type Inhibitors, H. E. Waldrip; Tubular Goods, F. A. Hunter, J. S. Abercrombie Co., Houston;

Tubing Calipers, W. F. Oxford, Jr., Sun Oil Co., Beaumont, Texas; Inhibitor Injection Methods and Practices, P. P. Spafford, Stanolind Oil and Gas Co., Houston; Well Completion Methods, H. L. Bilhartz and H. E. Greenwell; Metallurgical Factors, F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla., Laboratory Studies of Film Formation, Edward C. Greco, United Gas Corp., Houston; Acidity of Condensate Well Waters by D. A. Shock, Continental Oil Co., Ponca City, Okla.; Laboratory Studies on Corrosion in Carbon Dioxide and Organic Acid, R. B. Chesney, Sunray Oil Corp., Tulsa;

Polar Constituents of Well Streams by Louis J. Hillenbrand, Jr., United Gas Corp., Shreveport, La.; Field Histories, Morris Bock, Sun Oil Co., Dallas.

An appendix lists laboratory methods useful in condensate well corrosion and a short discussion on corrosion control practices used by 26 companies surveyed by the committee.

Electrochemical Constants. National Bureau of Standards Circular 524. 5½ x 9 inches, 310 pages, cloth. 1953. Proceedings of the NBS Semicentennial Symposium on Electrochemical Constants held at the NBS on September 19-21, 1951. Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., Per copy, $2.

This volume includes 29 papers and one abstract of the material delivered at the 1951 symposium on electrochemical constants. The discussions pertain to the theoretical and practical problems related with determination of electrochemical constants, including equivalent conductances, transference numbers, electrode potentials, ionization constants, activity coefficients and the parameters of electrode kinetics, polarography and electrophoresis.

Organic Protective Coatings. 6 x 9 inches, 387 pages, cloth. 1953. By William Von Fischer and Edward G. Bobalek. Reinhold Publishing Corp., 330 West 42nd St., New York 36, N. Y. Per Copy, $7.50.

The books consist of contributions from 18 authors from several industrial areas and technical organizations.

The contents include consideration of paint as an engineering material, a discussion of the pigment dispersion problem, use and function of anticorrosive pigments, vinyl resins, aminoplast resins, hot spray lacquers, formulation of emulsion and latex paints, synthetic resins and silicone resins. Other topics, not related to corrosion, are covered also.

The chapter on metal protection with synthetic resin coatings by E. E. McSweeny, Battelle Memorial Institute, lists numerous data on the chemical resistance, application technique, surface preparation, permeability of films and other significant information related to the topic.

The book is fully illustrated and includes an extensive topical index.

Russia Said to Lead U. S. In Number of Engineers

Peacetime uses for atomic power and a comparison of the number of engineering graduates in the U. S. and in Russia were the subjects of addresses by prominent government officials before the national meeting of the American Institute of Chemical Engineers in Washington, D. C., March 7-10. Donald A. Quarles, assistant secretary of Defense, commenting on Russia's engineers, said the Soviets are turning out about twice as many engineering graduates as the U. S. Dr. Henry D. Smyth, member of the Atomic Energy Commission spoke on "The Development of Nuclear Power for Peaceful Purposes." A special symposium on technical and patent aspects of industrial atomic power development also was scheduled.

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Requests for reprints of technical or other material published in CORROSION should be addressed to NACE's Central Office, 1061 M & M Bldg., Houston 2, Texas.

Dust Problem Solved

When Consolidated Water Power and Paper Company, Appleton, Wis. started burning spent sulfite liquor instead of discharging it into nearby waterways a problem arose concerning collection of the extremely fine dust resulting from the burning liquor. A dust collector was supplied for the job which proved to function satisfactorily. An examination showed approximately 96 percent of the dust collected to be particles under 7½ microns.

This was reported in *The Project Engineer*, Vol. 13, No. 3, 4 (1954) March.

Carbide Seminar Book

Proceedings of the University of Pennsylvania-American Society of Tool Engineers carbide seminar have been published. Considered during the 5-day session were: Economics of carbide in today's business, tool fabrication and maintenance, single point tooling results and analysis, outstanding new carbide applications such as milling, gun drilling, trepanning; and detailed data on heat, impact and corrosion resistance. The entire proceedings, bound, with charts, photographs, etc. can be obtained for $3.00 from Professor Lee N. Gulick, school of mechanical engineering, University of Pennsylvania, Philadelphia 4, Pa.

Report on Heating

Research into heating and ventilating problems being done in European and other foreign countries was the subject of a talk by R. S. Dill, chairman of the committee on research of the American Society of Heating and Ventilating Engineers. Mr. Dill presented the observations of G. V. Parmelee, research associate, ASHVE Research Laboratory, who recently made a tour of European installations after completion of his work as technical advisor in building design to the government of Israel.

Pennsylvania ASM Meet

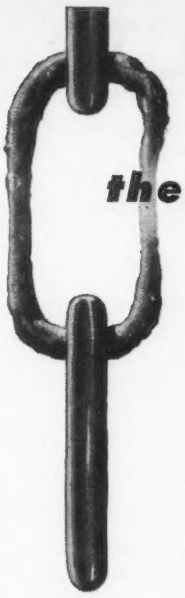
The ninth biennial Pennsylvania Interchapter meeting of the American Society for Metals will be held at the Pennsylvania State University on June 18 and 19. Participating chapters are Lehigh Valley, Northwest Pennsylvania, Penn State, Philadelphia, Pittsburgh and York.

Building Porcelain Book

"Porcelain Enamel in the Building Industry" is the title of a 160-page publication available from the Building Research Advisory Board, 2101 Constitution Ave., Wash. 25, D. C. The book contains over 100 illustrations plus a quantity of graphs, charts and tables.

New Aid for Engineers

A special pencil has been designed to help corrosion engineers figure out tough problems. Called a "headache pencil," it has aspirin tablets stored in its barrel. The pencil was one of many new advertising specialties shown at an advertising association meeting held in Chicago.



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Experience proves that the finest protective coatings available fail when applied over an inadequate primer. Inexpensive "cure-all" primers which permit the top finish coat to peel, split or chip off, obviously reduce the expected life of the protection.

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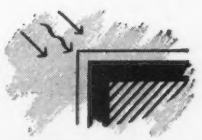

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Gates Engineering Co., Wilmington, Del. has established a technical-sales school for distributors' salesmen.

•

Corrosion and How, When and Where to Use Non-Metallic Materials will be topics discussed at the Basic Materials Exposition at the International Amphitheater, Chicago, May 17-20.

•

Ladish Co., Cudahy, Wis. has purchased the assets of Tri-Clover Machine Co., Kenosha, Wis. by purchase of the capital stock. The Tri-Clover Company will continue to function as a division of the Ladish Company.

•

Elprene, an elastic maintenance coating for light corrosion service has been developed by Atlas Mineral Products Co., Mertztown, Pa.

•

Stainless Steel has been used in the fabrication of a new pilot flame burner for use in gas operated appliances, by Robertshaw Thermostat Division, Youngwood, Pa.

•

Techalloy Company, Inc., Rahns, Pa. will cold-draw nickel, Monel and Inconel from ½-inch to .002-inch and Techalloy stainless steel wire from ¼-inch to .002-inch. Special attention will be given to close material and tolerance control.

•

Aluminum's use in architecture, especially in multiple story office buildings is described and illustrated in four compilations of data in file folders. The data, designated Alcoa Series 100-1,2,3 and 4, covers the details of construction involving the use of aluminum in two office buildings, a hospital and a school. Architectural elevations of the aluminum modules are included as are estimates of their cost relative to alternative construction.

T. W. Kuhlman Co., 2978 W. Genesee St., Lapeer, Mich. is marketer of pipe welding tools. One product, the Jewel welding flange clamp, lines the face of the flange at a perfect right angle to the pipe and holds it there until it is tacked.

•

Ladish Co., Cudahy, Wis. recently published a new fittings catalog on seamless welding fittings, forged flanges and forged steel fittings. The new book devotes 200 pages to dimensions and specifications. It also contains various tables on flow through orifices, friction loss, properties of pipe and other information. The book may be obtained by writing the firm.

•

The Annin Co., 6570 E. Telegraph Rd., Los Angeles 22, Cal., is marketing a new addition to the firm's line of high pressure control valves. Designated Series 34, the valve is designed for pressures to 6000 psi and temperatures to 900 degrees F.

•

Aluminum Co. of America, 1501 Alcoa Bldg., Pittsburgh 19, Pa., reveals a new use for corrugated aluminum siding. Through use of a "sandwich" wall with one-inch thick glass fiber insulation "filler," it is possible to erect a wall with twice the insulation value of a 12-inch masonry wall. The new type construction was used in building the heavy press plant for the U. S. Air Force at the Cleveland, Ohio works of the Aluminum Company of America.

•

E. I. du Pont de Nemours & Co., Wilmington, Dela., is selling Freon 13, monochlorotrifluoromethane, a nonflammable and nonexplosive refrigerant designed for systems producing temperatures in the range of minus 70 to minus 150 degrees F. Freon 13 has excellent chemical stability and is non-corrosive to metals and other components of conventional refrigeration equipment, the company claims.

•

Epocast III, a new epoxy resin, has been developed by and is now available from **Furane Plastics, Inc.,** 4516 Brazil St., Los Angeles 39, Cal. The new resin is intended for use in casting, potting and laminating. Toxic hardeners are not required to achieve cure and heat resistance of the cured product is considerably superior to most other low temperature curing epoxies, the company's literature says.

•

Brookfield Engineering Laboratories, Inc., Stoughton, Mass., makers of the **Brookfield Synchro-Lectric Viscometer,** have published a 20-page booklet explaining use and care of the instrument.

•

Dow Corning Corp., Midland, Mich., has developed an entirely new class of vehicles for protective coatings. Copolymers of silicone and oil-modified phenolic resins, they are designed to supplement conventional phenolic resins for applications where added resistance to heat, weathering chemicals and moisture is desired.

•

Bart Manufacturing Corp., Belleville, N. J., is producer of nickel clad steel plate through electro-deposition of pure nickel on mild steel plates with the cladding on either or both sides. The clad metal is suitable for fabrication into all types of storage tanks, chemical processing vessels and other types of equipment and installations where corrosion or contamination are problems.

•

Franklin C. Wolfe Co., Culver City, Cal., has developed a method of sealing flush rivets and screws to provide a seal against gases or fluids at high and low pressures. The seal consists of a rubber ring which fits around the shank of the rivet.

•

Gulf Oilcoat T, a new rust preventive, has been developed by the Gulf Oil Corp., Gulf Bldg., Pittsburgh, Pa. A compounded oil with a non-metallic high potency additive to prevent corrosion and rust of metal surfaces, the new product is especially applicable for protection of machinery during shipment, storage or seasonal shutdowns. An important feature is that it is compatible with machine lubricating oils.

•

The Ceilcote Co., 4874 Ridge Rd., Cleveland, Ohio, is distributing a new 4-page illustrated catalog entitled "Corobond... An Improved Bonding Cement for Brick and Tile." It presents technical and general information on the new acid-proof, alkali-proof and solvent-proof synthetic resinous bonding cement for joining brick and tile.

•

Teflon filter cloth, suitable for use with chemicals except fluorine gas, molten alkali metals and trichlorine fluoride is now being manufactured by National Filter Media Corp., New Haven 14, Conn. The cloth is said to be wholly resistant to molds, mildew and sunlight.

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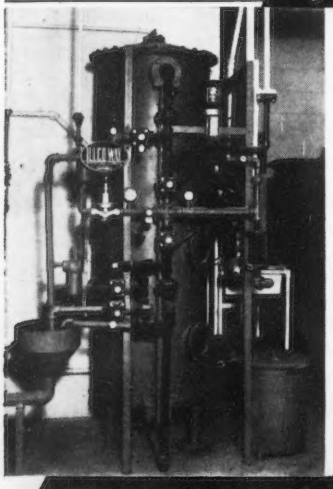

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PERSONALS

Irvin H. Fullmer, an authority in the field of precise length measurements and screw thread standardization, has been appointed chief of the National Bureau of Standards Engineering Meteorology Section, formerly designated the Gage Section.

•

Alfred L. Hartridge and **Stuart F. Kosters** have been elected vice presidents and **Thomas W. Barry** appointed an assistant treasurer of Stone & Webster Engineering Corp., New York, and Boston.

•

C. R. Sorber, Jr., recently has been appointed Cincinnati District Supervisor for the Metal Processing Department of the Pennsylvania Salt Mfg. Co.

•

Chemical Coatings & Engineering Co., Darby, Pa., has appointed **Richard Chancey**, Box 143, Jacksonville, Fla., to represent the firm in the sales and service of Neoprene linings, sealer and protective coatings.

•

Henry P. Seymour has been appointed manager of sales for V-Corr, a product of the Bettinger Corp., Waltham, Mass. V-Corr is the trade name of the firm's corrugated roofing and siding, steel coated with enamel.

•

P. J. Kern, Jr., has been appointed to the staff of the Colonial Iron Works Co. He will head the company's Karbate Service activities.

•

Robert J. Keating has been appointed head of the newly formed Industrial Waste Department of the Graver Water Conditioning Co. His efforts will be directed on problems of waste treatment for industry.

•

New vice-president and general manager for the Garfield Wire Division of the Overlakes Corp. is **Eric B. T. Kindquist.** Mr. Kindquist formerly was wire mill superintendent and assistant works manager for the Eastwod Nealley Corp.

•

George M. Pro has been named a partner in Air Placement Equipment Co., Kansas City, Mo. He will be in charge of design and development of new products. The firm now manufactures the Bondactor, concrete gunning equipment and the Mix-Elevator, a mixing and elevating machine.

•

Omar V. Greene has been appointed general sales manager for the Carpenter Steel Co., Reading, Pa. At the same time, the company named **John W. Thompson,** manager of sales development, a new staff assignment.

•

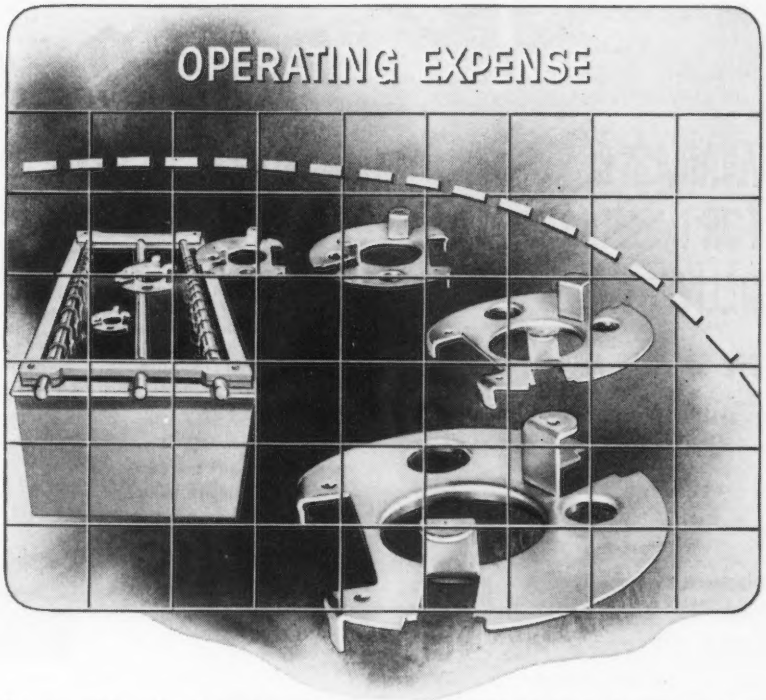
Roland J. La France has been appointed manager of the paint sales division of the Joseph Dixon Crucible Co., according to an announcement by H. E. Ehlers, industrial sales manager. Mr. La France will concentrate on expanding the Dixon distributor program.

•

Terrence H. M. Taylor, former research scientist with the U. S. Atomic Energy Commission has been named chief engineer of Rockwell Manufacturing Company's Nordstrom Valve Division plant at Oakland, Cal.

SARAN RUBBER RESISTS FLUOBORATE PLATING SOLUTIONS

Plating Tanks Lined with Saran Rubber Reduce Operating Expense by Eliminating Contamination, Corrosion and Current Leakage



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On CPS Graphite Anodes

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With standard 3' or 5' lead wire at no extra cost. Large stocks of unfinished cylinders permit prompt shipments of any length lead wire of #4, #6 or #8 direct-burial cable (Including heavy-wall polyvinyl insulation in oil-soaked soils).

CPS graphite anodes must pass standard 300 lb. quality control tests. Periodic tests to destruction are also made. In destructive tests the wire separates BEFORE the CPS ferrule attachment with the wire fails.

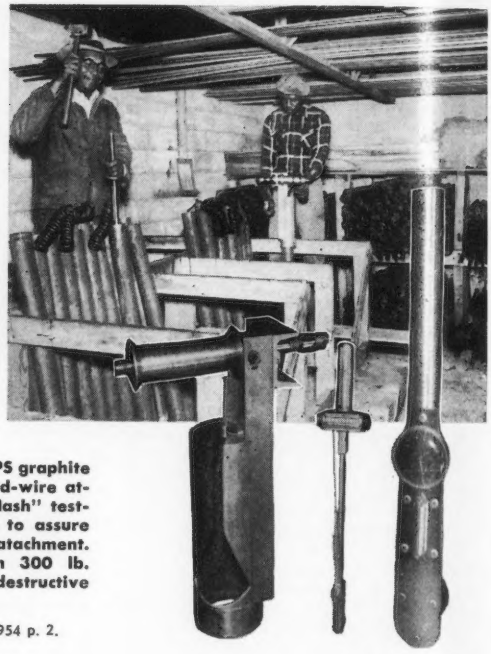

Photo above shows testing of CPS graphite anodes for permanency of lead-wire attachment. At right (A) "Tarkflash" testing device developed by CPS to assure quality control of lead-wire atachment. (B) Non-destructive minimum 300 lb. setting wrench (C) Indicating destructive tester.

*See "Graphite Electrodes"—*Industrial and Engineering Chemistry*—Jan. 1954 p. 2.

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Detectron Pipe Locators
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Corrosion Abstracts

Index to CORROSION ABSTRACTS

Vol. 10 May, 1954 No. 5

Page

3. CHARACTERISTIC CORROSION PHENOMENA
- 3.4 Chemical Effects 113a
- 3.5 Physical and Mechanical Effects.. 114a
- 3.6 Electrochemical Effects 118a
- 3.7 Metallurgical Effects 122a

4. CORROSIVE ENVIRONMENTS
- 4.2 Atmospheric 124a

5. PREVENTIVE MEASURES
- 5.2 Cathodic Protection 124a
- 5.4 Non-Metallic Coatings and Paints.. 126a

6. MATERIALS OF CONSTRUCTION
- 6.4 Non-ferrous Metals and Alloys—Light 128a
- 6.6 Non-Metallic Materials 128a

7. EQUIPMENT
- 7.1 Engines, Bearings, and Turbines... 128a
- 7.2 Valves, Pipes and Meters..... 129a
- 7.7 Electrical Telephone and Radio.... 129a

8. INDUSTRIES
- 8.4 Group 4 ..... 129a
- 8.8 Group 8 ..... 130a
- 8.9 Group 9 ..... 130a

3. CHARACTERISTIC CORROSION PHENOMENA

3.4 Chemical Effects

3.4.4, 3.5.9, 3.5.11, 3.7.2

The 'Inverse Dependence' of Metallic Corrosion on the Intensity of the Aggressive Factor. (In German). G. SCHIKORR *Metall*, 6, 13/14, 356-360 (1952) July.

The author refers to cases where an apparent increase in a corroding factor leads unexpectedly to a reduced rate of attack. For example, zinc exposed to the vapor above acetic acid solutions is corroded most rapidly at an acid concentration of 5 percent; for cadmium the figure is 20 percent. These facts are explained by the fall in the water vapor pressure. The addition of magnesium salts to sodium chloride solutions reduces their corrosiveness to zinc, and the attack on zinc by distilled water is fastest at 70°C. The effects of certain impurities in zinc on its solution by non-oxidizing acids are also quoted.

Factors which seem in some cases to have a corrosion-inhibiting effect are: increased concentration of salts or acid, quantity of attacking agent (e.g., iron in sea water), movement of attacking fluid, increase in temperature, rain, composition of attacked metal. Numerous examples.—BNF. 6054

3.4.9, 5.9.4, 2.3.5, 6.4.2

Effects of Water Vapour on the Electrical Properties of Anodized Aluminium. F. ANSBACHER AND A. C. JASON. *Nature*, **171**, No. 4343, 177-178 (1953) Jan. 24.

The capacity of an aluminum condenser which consisted of commercial purity aluminum wire 1/16 in. in diameter was measured. The wire was anodized and a thin metallic layer of aluminum evaporated on to the oxide film. This was placed in an enclosure in which water vapor was admitted under controlled conditons. Results were as follows:

$R_c = 0.73\ R_H$ when $0 < R_H < 0.5$

$R_c = 1.12\ R_H - 0.18$ when $0.5 < R_H < 1$

where R_c is the change of capacity relative to the maximum change of capacity (that is, at the saturation vapor pressure) and R_H is the relative humidity. The leakage resistance R, of the aluminum oxide at 50°, 60° and 70° C. was found to decrease exponentially with increasing water vapor pressure p. In each case the relationship can be expressed as: $R = R_o \exp(-p/p_o)$ where

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ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario.

AWWA—Journal, American Water Works Association, Amer. Water Works Asoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CBEC—Centre Belge d'Etude de la Corrosion (CEBELCOR), 17 re des Drapiers, Brussels, Belgium.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

IIM—Transactions, The Indian Institute of Metals, 23-B, Notaji Subhas Road, P. O. Box 737, Calcutta, India.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana, Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

SE—Stahl Und Eisen, Verlag Stahleisen, M. B. H., Dusseldorf, August-Thysen Str. 1. Postscheck Koln 4110, (22a) Dusseldorf, Germany.

TIME—Transactions of Institute of Marine Engineers, 85 The Minories, London EC 3, England.

UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

where R_o is the resistance at zero vapor pressure and p_o is a constant at a given temperature.—ALL. 6089

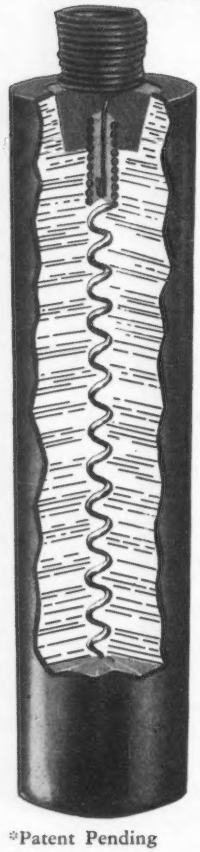
3.4.10, 6.3.14

Studies in the Corrosion of Metals Occasioned by Aqueous Solutions of Some Surface-Active Agents. Pt. III. Tin. T. K. Ross. *J. Applied Chem.* (London), **2,** Pt. 9, 526-531 **1952,** Sept.

The action of dilute aqueous solution of representative anionic, cationic, and non-ionic wetting agents on sheet tin has been studied, using 1. distilled water and 2. London tap-water with and without Zeolite softening treatment. The effects of varying the temperature and pH of the solution were also investigated. Most of the anion-active agents were corrosive towards tin, exceptions being sulfonated castor oil, which was practically inactive, and sodium alkylarylsulphonate, with which attack was very slight. With two of the cationic compounds moderate corrosion, increasing with increasing concentration, was noted, but no attack on tin immersed in triethanolamine solution was observed, though a precipitate of magnesium (hydroxide) was deposited on the tin when these solutions had been made up with tap-water. The sample of the non-ionic group examined produced no measurable attack, but the whole surface of the tin specimens was in many cases covered with colored films after immersion. In general, tap-water solutions were less corrosive than those in distilled or softened water, and the effects of pH changes were very variable. The results are graphically expressed, and a mechanism is suggested.—MA. 5887

Another First

for Standard's Anodes



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The perfect bond . . . Solidly bonded wire extends full length of expendable magnesium.

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*Patent Pending

Standard Magnesium Corporation
TULSA, OKLAHOMA

3.5 Physical and Mechanical Effects

3.5.8

Evidence of Corrosion Failures in Drill Stem Members. A. P. Farr. *Corrosion,* **9,** No. 4, 108-111 (1953) Apr.

Corrosion fatigue occurs in drill stems during drilling operations, cracks developing as a result of simultaneous action of cyclic stressing and corrosion pitting. Fatigue failures will occur without the presence of corrosion, but they occur quicker with corrosion present. Efforts to reduce corrosion fatigue failures were made by Hughes in 1932 when it was recommended a protective coating be applied or that a zinc wire be wrapped around the pipe under the counterbore of the tool joint. This problem was solved by welding the tool joint to the pipe, preventing the mud from reaching threads in the vulnerable zone. Zones of various drill stem members with greatest susceptibility to corrosion are illustrated. Failures in zones adjacent to unengaged threads in bottom of drill collar are vastly accelerated under corrosive conditions.

It is possible, by inspection, to anticipate corrosion fatigue failures by detection of cracks. Preliminary tests indicate that under corrosion fatigue conditions depth of a crack for a given length is proportional to the severity of corrosion.

Corrosion of drill collar boxes is frequent and serious. Practically all failures of drill stem members result in difficult fishing jobs. 6111

3.5.3, 6.6.6, 8.4.3

How to Combat Erosion in Fluid Cat Crackers. J. S. Clarke. Standard Oil Dev. Co. *Oil Gas J.,* **51,** No. 46, 262-264+ (1953) Mar. 23.

Considerable progress was made in reducing and combating erosion so that it is now accepted as a routine maintenance matter. Various test programs were carried out by Standard Oil Dev. Co. to evaluate some of the uncertainties regarding erosion. The first was a lab program in which a jet of catalyst-laden air was made to impinge upon sample plates of various metals to determine relative erosion rates. Another investigation was made to determine the ability of non-metallic castable refractories to resist erosion.—INCO. 6246

3.5.3, 7.1, 7.3

Cavitation. E. Crewdson. *Engineer,* **195,** 122-123 (1953) Jan. 23.

Cavitation attack can produce a spongy surface as though the metal had been chemically attacked or cause depressions as though the metal had been repeatedly struck with a ball-ended hammer. The spongy type of attack is characteristic of cavitation in water turbine runners near their discharge surfaces. The hammer-blow attack is common on the bosses of ships' propellers. Both of these types of cavitation damage can be fully explained as the result of attack by highly compressed bubbles of vapor or gas. The major part of the energy available for the attack is stored in the bubbles and not in the surrounding water. The high temperatures attained in the bubbles assist the attack and in some cases may be the primary cause of dam-

age. The resulting temperature gradients in the metal attacked may produce thermoelectric effects which will lead to electrolytic attack, particularly in sea water. Cavitation seems, therefore, not to be the result of bubble collapse, as maintained by some. Such collapse, in the author's opinion, cannot occur. High pressure and high temperature of the gas within the bubble can, however, account for all types of damage observed under cavitation conditons.—PDA. 6271

3.5.8

Fretting Corrosion. IV. *Allen Eng. Rev.*, 1953, 12-15, Jan.

Covers data on gauge plate steel (0.87% carbon, 0.51% chromium); phosphate-coated mild steel; electrodeposited cadmium and chromium; Inconel; K Monel; nickel (annealed, C. D. H., electrodeposited); electrodeposited silver; and Stellites Grades 6 and 12. Results of investigation as a whole are discussed and evaluated. Detailed information on effects, beneficial or otherwise, of lubricants, and advatageous effects of white lead alone or with molybdenum disulfide (all work on mild steel) are given. Methods of preventing fretting corrosion are evaluated.—INCO. 6119

3.5.8, 1.2.2, 8.4.3

Drill Stem Corrosion in West Texas. STANLEY C. MOORE. *Corrosion*, 9, No. 4, 112-113 (1953) April.

Each of the 700 or more drilling rigs operating in West Texas has an investment of $30,000 to $70,000 in drill stem and one drilling company there estimates drill stem costs on each rig to be $137 a day. A large part of the cost is attributed to rapid depreciation of drill stem from corrosion and corrosion fatigue, heavy corrosion from underlying salt strata being the principal culprit. Deeper wells drilled recently have faced an increasing corrosion problem as a result of reduction in salt content of well fluids.

The very costly results of corrosion fatigue failures of drill collar joints is cited, including the numerous operational difficulties resulting from mitigation measures.

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3.5.8, 2.3.7, 5.3.2

A Practical Evaluation of Metallic Coatings as Affecting Sensitivity to Stress-Corrosion Failure. C. H. HANNON. General Electric Co. *Metal Finishing*, 50, No. 10, 65-66, 71 (1952) Oct.

Evaluation of the effect of metallic coatings on the bolt member of transformer terminal clamps. The majority of evaluation tests were conducted by immersion in a mercurous nitrate solution with supplementing tests being conducted in an ammonia atmosphere. The eyebolts used were forged from an alloy of 91% copper, 7% aluminum and 2% silicon. The metallic coatings applied were composite electroplates of copper + nickel + chromium, copper + nickel

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+ tin, copper + silver, copper + tin, nickel + tin, and single electroplates of silver, cadmium, and tin. The data resulting from tests in ammonia are considered more significant in rating the effectiveness of various coatings, insofar as atmospheric stress-corrosion failures are concerned. Tables.—INCO. 6092

3.5.8, 2.4.2, 1.6

Symposium on Fretting Corrosion. 1953, 84 pp. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Penn.

A compilation of papers given by W. E. Campbell, J. R. McDowell, Oscar J. Horger, E. W. Herbek, Jr. and R. F. Stohecker, H. H. Uhlig, W. D. Tierney and A. McClellan. The booklet also includes an introduction by T. E. DeVilliers and a general discussion of the five papers presented. Mr. Campbell discusses fretting wear of metal surfaces from the broad view. Fretting corrosion is revealed to be of an unusual type—a corrosion of "oscillatory relative motion." This motion between supposedly-fixed, mating parts is shown to cause gross slip between the surfaces sometimes accelerated by abrasive oxide films formed as a result of the wear. Some ways of mitigating the slip and suggestions of future research regarding the mechanism are given. Valuable information was given by Mr. McDowell as the result of work in which he subjected to the conditions of fretting corrosion a large number of combinations of different metals so that he could compare the susceptibility of these to this "corrosion of motion." Regarding remedies he has some interesting comments to offer. To anyone concerned with the increasing number of service failures occurring in all types of machinery and equipment due to fretting, Mr. Horger's encouraging results on improving fatigue resistance by minimizing fretting corrosion should be helpful guides on further research. Messrs. Herbeck and Stohecker's paper gives results of research evaluating effects of some basic characteristics of lubricants on fretting in delaying or minimizing wear from this phenomena. Messrs. Uhlig, Tierney and McClellan's paper describes a test machine designed and constructed to measure fretting corrosion by weight loss under precisely defined conditions. The booklet is well illustrated with color and black and white photographs. Papers in the symposium were discussed by experts in the field concerned and their comments are included. 6299

3.5.8, 3.4.1

Chemical Causes of Wear. J. J. BROEZE. *Engineering*, **173,** 693-694 (1952) May 30.

Discusses 3 typical fields in which chemical causes of wear, of practical significance, have been identified: general lubrication, where there is chemical attack by the atmosphere; in engine and gear lubrication, with chemical attack by the lubricants; and in engine lubrication, with chemical attack by the combustion products. Data are charted. —BTR. 5984

3.5.8, 3.5.3, 5.9.4

Wear Phenomena. F. T. BARWELL. Paper before Inst. of Metals, Symposium on Properties of Metallic Surfaces, Nov. 1952. *Automobile Engr.*, **43,** No. 563, 77-80 (1953) Feb.

A discussion on wear phenomena which includes effects of lubrication and the nature of the superficial layer, running-in and removal of particles of material, abrasion and fretting corrosion, functions of oxide in continuous and prolonged sliding, modification of the bearing surface, changes below the surface, artificially modified layers such as phosphate coatings and anodized surfaces, and surface layer reaction with a lubricant. Reference is made to steel, copper, and ferrous specimens. 15 references.—INCO. 6254

3.5.8, 3.7.2, 6.2.3, 6.2.4

Intergranular Stress-Crack Corrosion of Plain Carbon and Low Alloy Steels and Its Prevention by Titanium or Tantalum-Niobium Additions. E. BAERLECKEN AND W. HIRSCH. VDE Comm. for Materials, Report No. 842. *Stahl und Eisen*, **73,** No. 12, 785-789 (1953) June 4.

Effects determining the occurrence of stress-crack corrosion are discussed. Steel tubes, including 18-8, were tested in a boiling solution of calcium-ammonium-nitrate. Prevention by adding titanium or tantalum-niobium to the steel was compared with addition of aluminum. Welds resistant to caustic embrittlement are described.—INCO. 6283

3.5.8, 4.4.7

Lubricant Corrosion is Being Licked. F. L. LAQUE. Inco. Paper before ASME & ASTM, New York, Feb. 29, 1952. *Chem. & Eng. News*, **30,** No. 11, 1098 (1952) March 17.

Corrosion by lubricants is no longer a major problem. Molybdenum sulfide when properly applied appears to be superior to all other lubricants in preventing fretting corrosion. Crevice corrosion overcome by design was also discussed. —INCO. 5979

3.5.8, 7.3, 8.9.5

Corrosion-Fatigue Failure of a Marine Propeller Shaft. CARL A. ZAPFFE. *Corrosion*, **9,** No. 9, 298-302 (1953) Sept.

An unusually clear example of corrosion-fatigue failure is used as a basis for discussing those forms of fracture in which chemical attack combines with mechanical stress to destroy an engineering structure. The term "mechanochemical" is introduced to cover the entire category of stress-corrosion, corrosion-fatigue, metal-fusion, stress-rupture and related types of attack; and a new fracture terminology is given for precise description of fracture details. A generalized thermodynamic theory is then proposed on the basis of $\Delta F = f(T,X,P)$ where fissuring results from stress-imposed changes in thermodynamic microsystems such as a. grain boundaries to produce intergranular separations and b. subgrain or micellar boundaries to produce transgranular cracking. 6145

3.5.9, 2.3.4, 2.4.2, 4.3.2, 4.3.3

Corrosion by Aqueous Solutions at Elevated Temperatures and Pressures. F. H. BECK AND M. G. FONTANA. *Corrosion*, **9,** No. 8, 287-293 (1953) Aug.

Recent trends in the chemical industry are in the direction of higher temperatures and pressures. Few data are available in the literature on corrosion of metals and alloys at temperatures above the atmospheric boiling points of the solutions. This paper presents data on the corrosion of a variety of metals and alloys by nitric, phosphoric, acetic

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acids and sodium hydroxide at temperatures up to 425°F. The metals and alloys include CF-8, CF-8M, CN-7MCu, CB-30, cast titanium and high silicon iron. In general, corrosion increases rapidly as the temperature is raised above boiling and in some cases very rapid and previously unexpected attack occurs. Some data at lower temperatures are included for comparison. Data are also presented on the inhibiting effects of metallic ions in solution and in some cases spectacular decreases in corrosion rates are observed. An example is the effect of copper ion on corrosion of stainless steel by phosphoric acid. Sub-surface corrosion of stainless steel by hot caustic is described. Borderline passivity effects in hot acids are discussed. Equipment for conducting corrosion tests at elevated temperatures and pressures is described. 6121

3.5.9, 5.4.2, 2.2.5

High Temperature Ceramic Coatings in Industrial Application. D. K. Krosch. Solar Aircraft Co. *Materials & Methods,* **37,** No. 1, 162+ (1953) Jan.

They are prolonging life of heat treating fixtures, furnace parts, and equipment in processing industries. Tests are being made to find the value of coatings as protection against the corrosive effects of mild acids and alkalies in chemical processing and similar applications. Burner tubes made of Inconel, one coated, the other uncoated, were subjected to a field test. They were operated at 2000°F. After 136 hr. of operation, the uncoated tube was completely corroded and eroded. But after 566 hr. of operation, the ceramic tube was still in serviceable condition. Photographs.—INCO. 6136

3.5.9, 5.8.2, 4.4.3, 8.1.3

Accelerating Effect of Decreasing Temperature on Corrosion by Glycol Solutions. D. Caplan and M. Cohen. *Corrosion,* **9,** No. 8, 284-286 (1953) Aug.

The corrosion of galvanized steel in solutions of ethylene glycol containing borax is found to increase with decreasing temperature. This is believed to be due to the formation of a soluble complex zinc salt, the stability of which is greater the lower the temperature, which prevents the formation of a barrier film of insoluble corrosion product. Cadmium, magnesium and brass are attacked at low temperature in glycol-borax solution by the same mechanism, as is zinc in solutions of glycol containing sodium acetate or sodium benzoate. 6277

3.5.9, 7.1, 3.7.1, 2.3.7, 4.2.3

High Temperature Materials: Tests Used as Criteria of Service Behaviour. (In English). L. B. Pfeil. *Schweiz. Arch. angew. Wiss. u. Tech.,* **18,** No. 3, 88-97 (1952).

The properties required of materials for use at elevated temperatures in gas turbines are listed and methods of testing these properties are discussed. The significance of the onset of tertiary creep is emphasized, and it is shown that in Nimonic alloys tertiary creep begins at lower strains as the temperature rises and time increases. It is suggested that time of fracture is largely determined by some condition of the grain boundaries or by the balance between the properties of the grain boundaries and the grains and that optimum creep properties are obtained only by a controlled amount of over-aging, delayed cooling from the solution temperature or precipitation at a temperature higher than that which produces maximum hardness. There is a steady decrease in room-temperature fatigue properties with strain in tertiary creep. A Gerber diagram for Nimonic 80A at 700° & 750°C. is plotted. In studying the effect of vanadium in the fuel on the oxidation or high-temperature alloys, the amount and method of supply of the accelerating agent greatly influence the extent to which the rate of oxidation is affected. Nickel-chromium alloys are much more resistant to accelerated oxidation than iron-rich alloys, probably because nickel oxide in the scale is not fluxed by the vanadium pentoxide; however, the iron-containing materials are more resistant to sulfur which may also be present in the products of combustion, and vanadium pentoxide has been shown to stimulate sulfidation. A suitable balance of iron and nickel must be found for any particular ratio of vanadium pentoxide to sulfate in the fuel ash. Rig tests for thermal shock are also described. 25 references. —MA. 6086

3.6 Electrochemical Effects

3.6.5

Interpretation and Significance of Potentials of Metals in Aqueous Solutions. Morris Cohen. *Corrosion,* **9,** No. 10, 372-376 (1953) Oct.

The potential of a metal in an aqueous solution is dependent both on the reaction or reactions which are taking place between the metal surface and the environment and on the physical nature of the system. When a metal is corroding not only is the system not in equilibrium but there is usually more than one reaction taking place. The potential which is measured is therefore a mixed polarized potential. Because of this, the measured potential is a poor criterion of the corrosion resistance and must be considered in relation to the environment. The effect of the resistance paths in the system on the potentials are considered. Examples of the potentials of iron in various systems are given and the main factors determining these potentials are outlined. 6270

3.6.5

The Behavior of Metal Complexes in Aqueous Solutions. Arthur E. Martell. *J. Chem. Education,* **29,** 270-280 (1952) June.

Surveys ways in which properties of aqueous metal ions are affected by complex formation, with special reference to the formation of chelate compounds. Topics discussed are solubility, electrical conductance, interaction with hydrogen ions, absorption spectra, and oxidation potential. Graphs, diagrams, and tables. 39 references.—BTR. 5964

3.6.5, 3.5.8, 3.5.9

Electrochemical Reactions in Friction Systems at Elevated Temperatures and Their Effect on the Wear of Plant Machinery. (In German). H. Schiffers. *Metalloberflache,* Sec. A., **6,** A120-A124 (1952) Aug.

The magnitude of friction between two surfaces moving against each other under dry, normal-temperature conditions depends on the mutually exerted pressure, on the type of the materials, and on the nature of the surfaces. When a lubricating film is interposed between the two moving surfaces, the resulting internal friction theoretically is independent of the materials used; practically, however, differences up to 60% are not unusual in bronze/steel bearing systems, indicating that the choice of materials is of great importance for minimizing wear.

In automotive, locomotive, steam engine, turbine, and similar machine systems in which temperatures of 300-500° C., water vapor, combustion gases, and other chemical agents play an important role, the amount of purely mechanical wear is usually far exceeded by the losses caused by chemical and electrochemical phenomena. In ferrous systems, which in practice are the most important, the chemical reactions induced by the aging of lubricants invariably lead to the dissolution of considerable amounts of iron and the formation of inorganic and organic ferrous compounds. In addition, the two metallic parts of a friction system, though separated by a thin lubricating film, are usually connected by a common machine frame. During aging of this film, electrically conducting compounds are formed, and the entire friction system represents nothing less than a short-circuited galvanic cell having an oxidation-reduction (redox) potential independent on the electrolyte and dependent solely on the difference in the redox potentials of the two metal surfaces.

Electrochemical losses not accountable for by chemical corrosion alone have also been observed at high temperatures in non-frictional systems, in which two

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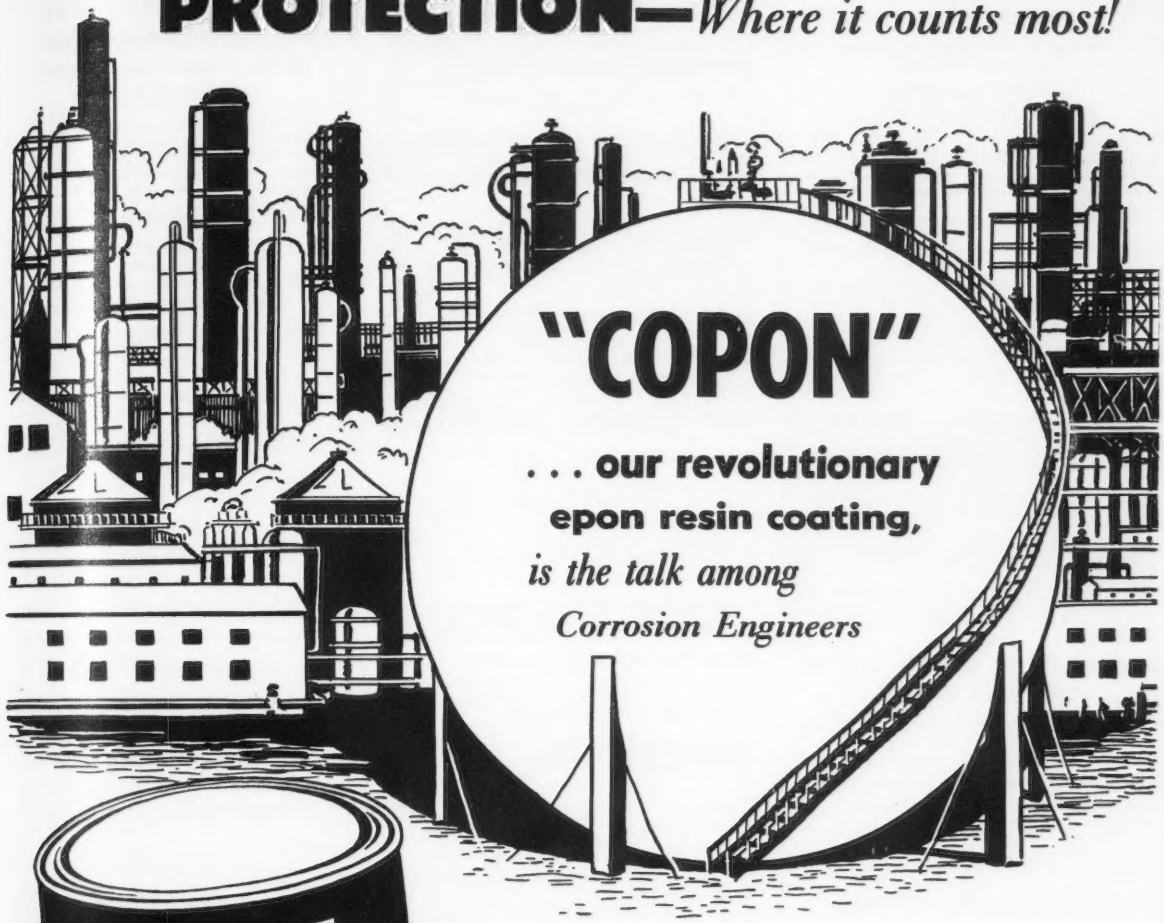

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different metal poles are connected metallically and separated by a weak acid or alkaline medium.

In conclusion, the two components of a metal friction system should be selected in such a way that the ratio of their redox potentials is as close as possible to one and, secondly, that their solution potentials are as low as possible. Where this is not feasible, the cheaper alloy should have the higher solution potential. Redox potentials of alloys can be controlled by suitable alloying additives and, possibly, also by changes in the production methods. Electrical insulation of the two poles of a friction system, wherever possible, will help to eliminate electrochemical wear.—PDA. 6078

3.6.6, 6.4.2

A Study on Corrosion and Its Protection of Aluminum Alloys in Contact with Dissimilar Metals. M. KATO, Y. NAKAMURA, Y. SHIOTA AND H. HACHIYA. *Light Metals* (Japan), No. 6, 71-82 (1953) Feb.

Several protective methods of aluminum alloys against corrosion in contact with dissimilar metals are compared. Those are that inserting zinc plate, cadmium plate and calking paste respectively combined to painting.

Tests were carried out in respect to the change of appearance and the decrease of tensile properties of alloys subjected to corrosion in 5.85% sodium chloride plus 0.3% hydrogen peroxide solution a month and 3 months. On the panel plate of 52S-O or ND-O a strip of mild steel or brass band was attached by means of mild steel rivets. Various combinations of vehicle and pigment as calking paste were tested on the protective effect against contact corrosion, resulting that the paste of alkyd resin containing aluminum powder, zinc powder and zinc-chromate was found to be the most effective. When aluminum alloy plate has not been painted, insert of zinc plate is the most effective, while the consumption of zinc is compara-

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How CORROSION Is Indexed

Annually, in December issue, a cross-referenced tabular topical index of the material published in the Technical Section is published. An alphabetical subject index will be published in the December, 1954 issue.
Annually, in December issue, an alphabetical author index is published.
Annually, in December, a tabular index to the Corrosion Abstract Section is published.
Monthly, technical articles published in Corrosion are abstracted in the Corrosion Abstract Punch Card Service.
5 Year Index, 1945-49, consisting of a cross-referenced tabular topical index and an alphabetical author index was published in the December, 1950 issue of Corrosion.
Bibliographic Surveys of Corrosion—Corrosion Technical Material is indexed in the NACE's Bibliographic Surveys.
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No indices of other sections of Corrosion are prepared by NACE.
All indexing is done, as far as practical, according to the NACE Abstract Filing System Index, which is used for NACE Abstract Punch Cards and the biennial Bibliographic Surveys of Corrosion.

tively large. When aluminum alloy plate has been painted, inserted zinc plate destroys the coatings, so the calking of paste between aluminum and dissimilar metal band before painting is the best. —JSPS. 6161

3.7 Metallurgical Effects

3.7.2, 2.2.2, 6.2.1, 5.4.5

Effect of Composition of Steel on the Performance of Organic Coatings in Atmospheric Exposure. F. L. LaQue and James A. Boylan. *Corrosion*, **9**, No. 7, 237-241 (1953) July.

The investigation provides at least a partial answer to the question as to whether improved atmospheric corrosion resistance of alloy steels is advantageous when they are painted. Steels showed a 20:1 difference in corrosion loss between an exceptionally low copper content open hearth iron and typical low alloy high strength steel. A common automobile paint system was used —a pigmented baking alkyd primer with pigmented baking urea modified, alkyd top coats, with and without zinc phosphate (Bonderite) pretreatment. Test panels were exposed 80 and 800 feet from the ocean at Kure Beach, N. C., in an industrial atmosphere at Bayonne, N. J., and in a rural atmosphere at Morenci, Michigan. Principal findings were: 1. Low alloy steel performed best; copper steel next. Low copper content open hearth iron worst, painted or bare. 2. Zinc phosphate pretreatment improved performance of all painted steels, the advantage increasing with severity of the atmosphere and vulnerability of steels. 3. Best performance was that of low alloy high strength steel, zinc phosphate pretreated. 4. A few weeks' exposure 80 feet from ocean led to same conclusions as exposure for much longer periods elsewhere. 5. Marine atmosphere 800 feet from ocean was less damaging to bare, but more damaging to painted steel than Bayonne industrial atmosphere. 6167

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3.7.2, 6.2.2, 3.5.9, 2.3.7

Some Notes on the Oxidation Resistance of Boron-Containing Chromium-Nickel-Cobalt-Iron Alloys. W. O. Binder and E. D. Weisert. *Corrosion*, **9**, No. 9, 329-332 (1953) Sept.

During an investigation of a series of cast chromium-nickel-cobalt-iron alloys, it became of interest to gain some indication of the effect of boron on the oxidation resistance of this family of alloys. A series of alloys containing 18 and 20 percent chromium with various balances between nickel, cobalt, iron and boron were subjected to oxidation tests in air at 1650, 1830 and 2012 degrees F. Temperatures somewhat above those encountered in gas turbine applications were chosen to accelerate the attack since the effect of boron was not readily noticeable at temperatures below 1650° F. Results of this investigation indicate that iron and boron and, to a lesser extent, cobalt have an adverse effect on the oxidation resistance. Molybdenum strongly decreases the alloys' resistance to oxidation. X-ray diffraction work indicated that protective Cr_2O_3 scales are not compatible with high boron contents, if the balance of the base alloy elements is not controlled. Boron was found to promote the formation of complex spinel and wolframite type oxides. It was concluded that while boron has an adverse effect on the oxidation resistance of chromium-nickel-iron-cobalt alloys, boron bearing alloys may be designed which have oxidation resistance comparable to those without boron by proper control of composition. This may be accomplished primarily by keeping the iron content below 6 percent, through the use of tungsten rather than molybdenum as a strengthening agent and by avoiding excessive cobalt contents, largely through replacement with nickel. 6085

3.7.3, 5.3.4

Effect of Annealing on the Resistance of Galvanized Steel to Atmospheric Corrosion. S. E. Hadden. *J. Iron Steel Inst.* (London), **171**, Pt. 2, 121-127 (1952)

The corrosion-resistance in an urban atmosphere of galvanized wire and sheet specimens annealed at 450°-650°C. was compared with that of specimens which had not been annealed. Annealing was found markedly to increase the corrosion-resistance, the lives of some of the specimens being more than 3 times those of the corresponding un-annealed specimens. The annealed coatings consisted entirely of iron-zinc alloys, the % of iron in the coating increasing with time and temperature of annealing; in the best specimens the coating contained 21.6% iron. The corrosion-resistance was found to increase with the iron content of the coating. The enhanced corrosion-resistance of the annealed specimens is ascribed to the formation of a thin black layer of corrosion product on the surfaces of the specimens; this layer partially water-

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proofs the specimen, thus slowing the rate of attack, and prevents rain from washing away the protective corrosion products which are produced on galvanized coatings. 7 references.—MA. 5941

3.7.3, 6.4.2

Recommended Practices for Spot Welding Aluminum and Aluminum Alloys. 1953, 33 pp. *American Welding Society*, 33 West 39th St., New York 18, N. Y.

This booklet, prepared by the American Welding Society's Resistance Welding Committee, includes sections on material characteristics, surface preparation, welding schedules, welding technique and defects and causes. A bibliography with 58 references on aluminum spot welding is included. 6232

3.7.3, 6.2.5

The Rapid Softening of Cold-Drawn Austenitic Stainless Steels. F. A. Hodierne and C. E. Homer. *J. Iron Steel Inst.*, **171,** 249-253 (1952) July.

A detailed study was made of the effects of softening treatment in properties and structure of five different stainless steels. Includes corrosion resistance, hardness and microstructure. Recommended conditions for rapid softening are described.—BTR. 5547

3.7.3, 6.2.5

Design Properties of Brazed Joints for High-Temperature Applications. Robert L. Peaslee and Willard M. Boam. *Welding J.* (N. Y.), **31,** 651-662 (1952) Aug.

Tells how, with a reducing atmosphere and nickel-chromium-base alloy, using suitable procedures and equipment, the brazing of stainless steel for high-temperature work can be successfully accomplished.—BTR. 5683

3.7.4, 6.2.5, 2.3.5

The Electrolytic Separation and Some Properties of Austenite and Sigma in 18-8-3-1 Chromium-Nickel-Molybdenum-Titanium Steel. T. P. Hoar and K. W. J. Bowen. Am. Soc. Metals, Preprint No. 4, 1952, 19 pp.

Gives details of experimental technique and of results obtained in above investigation. Transformations of extracted and massive austenite are compared. Ferromagnetic properties at low temperatures, compositions, and electrode potentials of the two varieties are also compared.—BTR. 5696

3.7.4

Contribution to the Problem of the Austenite-Martensite Transformation. G. A. Oding. *Vestnik Mashinostroeniya*, **32,** No. 3, 69-71 (1952).

Author's study of martensite transformation over entire temperature range of this transformation at a cooling rate not in excess of 5° F/minute, based on dilatometric method (in contrast to G. Kurdyumov's studies based on retained austenite and the use of magnetic analysis). Steel compositions studied: 1.2% carbon, tool steel; 1.4% carbon, manganese-chromium tool steel; silicon-chromium steel; 1% carbon, 1½% chromium bearing steel; chromium-tungsten and chromium-tungsten-manganese steels. Investigational procedure. Data on initial and final temperatures of martensite transformation and on temperatures corresponding to maximum rate of transformation of steels studied. Rate of martensite transformation over entire temperature range of this transformation for some of the steels studied. Quantitative data on transformation process. Conclusions drawn from results. (Translation available from Henry Brutcher, P. O. Box 157, Altadena, Calif.) 5989

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.3, 2.3.4

The Measurement of the Dewpoint and Sulfuric Acid Vapour Content of Combustion Products. W. E. Francis. Gas Research Board, Communication No. GRB 64, June, **1952,** 37 pp.

In connection with corrosion-prevention studies, deals with an electrical conductivity method for determination of sulfur dioxide-sulfur trioxide ratio in gaseous products of combustion and describes research work covering variation of this ratio with factors such as degree of primary aeration, type of burner, and sulfur content of gas. Table, graphs, and apparatus diagrams. 31 references.—BTR. 5967

4.2.3, 7.6.4, 2.4.2, 2.2.8

Investigation of Corrosive Nature of Flue Gases. G. G. Thurlow. *J. Inst. Fuel*, **25,** 252-255, 260 (1952) Nov.

One of the most serious problems encountered in watertube boilers in recent years has been the corrosion of the air heater and other low-temperature surfaces by sulfuric acid formed by the combination with water vapor of traces of sulfur trioxide produced in the boiler system and condensed out on surfaces at or below the dewpoint. The temperature-controlled mild-steel probe described in this paper was developed with the object of providing more direct information as to the mechanism of acid deposition and attack on metal surfaces. The function of the probe is to obtain a relative measure of the corrosive nature of the flue gases from a boiler rather than at this stage, to simulate the rate of corrosion obtained on any particular boiler surface. The instrument consists essentially of a prepared metal test surface placed at the end of a long probe. The surface is inserted into the gas stream to be examined and is maintained at a constant temperature, irrespective of fluctuation in the gas temperature. After a suitable period of insertion the probe is removed and the amount of corrosion of the test surface that has occurred ascertained. The design of the test head is as follows: A 1-inch diameter hemispherical mild steel test cap fits into a heat-insulating collar, a lip preventing air blowing directly over the external surface. A chromel and an alumel wire are welded into the cap about ½ inch apart and form the thermocouple used for measuring and controlling the temperature of the head. The unit is mounted on the end of a metal probe 6 feet long. Compressed air used for cooling passes up the center of this probe through an inner tube to the distributor. After blowing against the under-side of the cap, it discharges to atmosphere down the annulus between the tube and probe wall, so helping to keep down the metal temperature of the probe. A thermocouple in the cap is connected to a "Bristol" potentiometer pyromaster recorder. This pyromaster provides a permanent record of the temperature and maintains it at any selected value by making or breaking (dependnig on whether the recorded temperature is above or below a pre-selected datum) two relays which operate the two circuits controlling the direction of rotation of a 24 volt single-phase a.c. motor. This motor opens or closes a valve in the compressed-air line through a high-reduction gear.—MA. 5919

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 7.7, 6.3.6, 4.5.2

Effects of Polarization on Telephone Cable Buried Through a Salt Bed. Daniel R. Werner. *Corrosion*, **9,** No. 7, 232-236 (1953) July.

Cathodic protection has been applied to a copper jacketed cable in a salt lake bed about one mile wide in which the earth resistivity was apparently uniform at about 20 ohm-centimeters. Current of about one ampere flowed on the copper jacket into the low earth resistivity lake bed area from the higher earth resistivity areas on either side and was found to be sustained by polarization effects when the cathodic protection current was removed. The current loss on the copper jacket was found to be concentrated in an area about 720 feet wide, 360 feet each side of the point where the cathodic protection current had been drained from the copper jacket. The copper jacket to soil potential tested most negative to a copper sulfate half cell in the 720-foot area where the current loss was concentrated and was of the order of —1.0 to —1.1 volts. Permanent remedial measures will consist of installations of magnesium anodes distributed throughout the low earth resistivity area and insulating joints in the copper jacket at locations where large changes in the earth resistivity occur. 6147

5.2.3, 7.2, 8.9.3, 4.6.7

Cathodic Protection of Underriver Pipe Lines. C. C. Loyd and John R. Whitney. *Corrosion*, **9,** No. 9, 303-306 (1953) Sept.

Installation of cathodic protection on the 3100-foot portion of the one 12-inch and six 8-inch crude oil pipelines under the Mississippi River which connect the Baton Rouge Refinery and the Anchorage Tank Farm was completed in May, 1951. A current density of 3.5 milliamperes per square foot was used as the minimum requirement for full protection of the 52,000 square feet of surface area of these pipelines. A 100 ampere, 30 volt rectifier and a groundbed were installed on each bank of the Mississippi River to supply the protective current to the pipelines from both sides of the river. The groundbeds were designed to utilize the mutual interference effect of the anodes to force the current to flow toward the middle of the river and to secure overlapping protection from the two units. Pipe-to-soil potential measurements on both banks of the river indicate that over-lapping protection was achieved and that full protection to the pipelines has been accomplished. 6138

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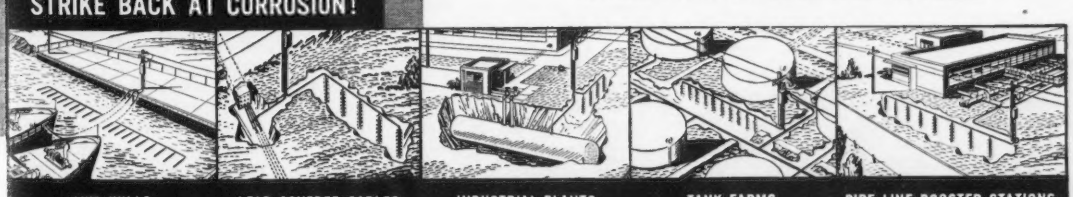

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5.4 Non-Metallic Coatings and Paints

5.4.2

Zinc Protects Trailer Parts From Corrosion. W. G. PATTON. *Iron Age*, **169**, No. 22, 82-84 (1952) May 29.

A zinc protective coating, Zincilate 300, used by Fruehauf Trailer Co. to protect steel parts and iron metal castings from corrosion is less costly than cadmium, gives good coverage, is unaffected by marine conditons, mild acids, alkalis, hot water up to 150°F and air temperatures up to 600°F and offers satisfactory resistance to gasoline, salt water, oils, greases and abrasives. Zincilate protection permits the use of carbon steel where corrosion-resisting grades such as galvanized sheet were used. Carbon steel, aluminum and stainless are used for the body size panels of the trailers. Application of the coating is described and other advantages are given. Illustrations.—INCO. 5954

5.4.2, 3.5.9, 4.3.1

High Temperature Ceramic Coatings for Chemical Use. W. A. BARROWS. Barrows Porcelain Enamel Co. *Products Finishing*, **17**, No. 5, 38-40, 42 (1953) Feb. Finish, **10**, 24-26 (1953) Feb.

Ceramic coatings designed to withstand higher temperatures than ordinary porcelain enamels can be used at 1600-1800°F. There are 2 groups of porcelain enamels and ceramic coatings: regular, which are suitable for use under normal atmospheric conditions with solutions free from acids and alkalies; and acid resistant, which are resistant to most acids except hydrofluoric acid. Four factors to consider for successful ceramic coatings are base metal, type of coating, design and fabrication. Porcelain enamel and ceramic coatings are used for coating chemical processing vats, acid storage tanks, brine tanks, chemical piping, and smokestacks. Photographs.—INCO. 6236

5.4.3, 3.3.4

Biological Deterioration of Polysulfide Polymers Employed as Linings for Gasoline Storage Tanks. F. H. ALLEN. (Stanolind Oil & Gas Co.) AND D. FORE, JR. (Naval Research Lab.). *Ind. & Eng. Chem.*, **45**, No. 2, 374-377 (1953) Feb.

Construction program of underground prestressed concrete tanks for storing fuel oil, Diesel oil and aviation gasoline. Polysulfide polymer linings of two types, Thiokol Type FA and Thiokol Latex Type MX were installed. It was found that attack of these linings by molds and bacteria under conditions of tropical temperature and humidity can be inhibited by treating the polysulfide linings with an appropriate fungicide, notably pentachlorophenol. Illustrations, 3 references.—INCO. 6097

5.4.5

Polystyrene Latex Emulsions and the Chlorinated Diphenyls. J. BRINDLE. *Chim. peintures*, **16**, No. 5, 173-184 (1953).

Data are given on the use of polystyrene latex in emulsion paints and of the chlorinated diphenyls in paints, varnishes and lacquers, and notably in anti-corrosive paints based on chlorinated rubber. Tables of compatibility and typical formulations are included.—RPI. 6218

5.4.5, 2.3.2

Performance of Pretreatment Primers as Revealed by Accelerated Weathering Tests. *Products Finishing*, **17**, No. 2, 46+ (1952) Nov.

The merits of a pretreatment of self-etch primer of a two-solution polyvinyl butyral resin/phosphoric acid type as the foundation for adherent and durable coatings of paint and enamel in industrial finishing were established by test procedures incorporating mild and severe hot humidity, salt spray and open atmospheric conditions. The range of metals used covered aluminum with and without chromic or sulfuric acid pretreatment, commercial brass sheet, mild steel sheet with and without an immersion phosphatizing, tinned iron or tinned steel sheet processed by the hot tinning method and mild steel, zinc or cadmium plated, both with or without phosphate pretreatment. The finishing enamels were a baking synthetic urea/alkyd resin type, baking 30 minutes at 250°F., and an ordinary grade cellulose enamel. These were tested with and without primer, the latter being a red oxide modified alkyd type baking 30 minutes at 250°F., an air drying aluminium powder pigmented cellulose medium, and a pretreatment etch primer, which was baked for 15-20 minutes at 250°F. As a result of the "weatherometer" test all the finishes lost gloss and chipped to a considerable degree. On the aluminum specimens there was loss of color and gloss resulting from chalking, but the enamel film was still firmly adherent to the base metal. Very little corrosion was apparent in the cross-scratches. With enamel finishes, only baked enamels were examined on aluminum. Primer and finish enamel performed badly under scratch and bend conditions, this applying to both plain and chromatized aluminum. One coat of enamel straight on the chromated surface however, was very good while the etch primer gave perfect results in both cases.—ALL. 5916

5.4.5, 5.9.4, 5.4.8

Emphasis Upon Finishing Armament Equipment. Parts I & II. *Ind. Finishing (Brit.)*, **4**; Nos. 46 & 47; 675-676, 678; 785-786 (1952).

The first part deals with the chromate protection for magnesium alloys and reviews the development of chromate solutions for protection against corrosion. Cleaning of the metal prior to chromating is discussed and the necessity for removal of existing chromate, paint or corrosion products is emphasized. Materials for this purpose are described. The second part considers immersion treatments for copper alloys and their effect on paint behavior. The protective qualities of a variety of paints, on magnesium alloys to different specifications, were compared. Among paints which gave good results were a black primer containing chlorinated rubber and systems employing zinc chrome. Phenyl mercuric acetate as a fungicide in paints for magnesium alloys was found to retard but not stop mold growth and to have no significant effect on the corrosion resistance of the coatings.—RPI. 6206

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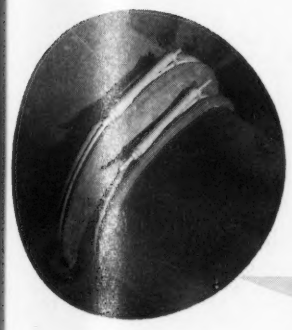

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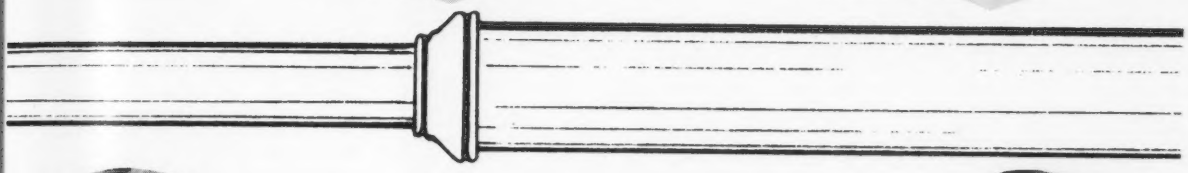

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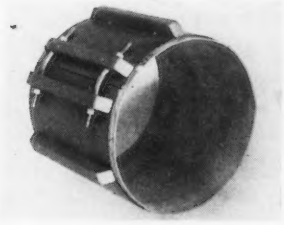

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6. MATERIALS OF CONSTRUCTION

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2, 5.9.4

Treated Aluminium Resembles Gold, Silver, or Chromium. *Chem. Eng. News,* **31,** No. 10, 1008, 1010 (1953) March 9.

The process, known as "D'Orium," developed in Switzerland four years ago, is an electrochemical oxidation process which forms an oxide on aluminum surfaces. It is claimed to give aluminum the appearance of such metals as gold, silver, and chromium. Either highly polished or a matte surface can be produced. A modification of the process provides electrochemical dyeing. The surface is said to be hard and to resist acid, alkalies, and weathering effects. Among the possible outlets are for jewelry, window frames, automobile trim, and skins for airplane fuselages. The United States Testing Laboratory has tested the material for ability to resist abrasion, corrosion, and weathering, and also hardness and wearability. The process has been licensed to Miracle Finishes, Inc., an affiliate of Crosby Products, Inc.—ALL. 6259

6.4.2, 5.9.4, 5.4.5

Aluminium and the Primer Problem. M. SCHENK. *Chem. Rundschau,* **5,** No. 13, 200-201 (1952); *Literatur-Bericht,* No. 15, 177 (1952); *Light Metals Bull.,* **14,** No. 25, 1001 (1952).

With aluminum the purpose of the primer is in the main to ensure good adhesion of the subsequent coatings. Adhesion is determined mainly by the aluminum oxide surface film. To improve the adhesion, the aluminum is usually treated in a mixture of chromic and sulfuric acids, in phosphoric acid, or by the Alprox process (alkaline and acid treatments). The M.B.V. process is less suitable. Additional corrosion protection is provided by anodic oxidation. The primer coating must not be brittle and should, of course, be compatible with the subsequent coatings. Adhesion is improved by the presence of drying oils with a stoving temperature above 150°C., the improvement being due to a combination of the fatty acids with the aluminum. The maximum stoving temperature will depend on the alloy and the mechanical properties required (Avional and Duralumin 80°C., other alloys 180°C).—RPI. 5913

6.4.2, 3.5.9

Sintered Aluminium With High Strength at Elevated Temperatures. R. IRMANN. *Metallurgia,* **46,** 125-133 (1952) Sept.

Discusses factors involved in the production of sintered compacts prepared from pure aluminum powder which are stronger and superior to pure aluminum and its usual alloys. Compares mechanical, physical, and corrosion properties with those of pure aluminum and a number of its alloys. Applications discussed. Diagrams, graphs, and micrographs.—BTR. 5944

6.4.4, 5.4.5

Wash Primers for Magnesium. A. R. HEMPEL, H. W. LASCH, G. SCHURR, M. VAN LOO. *Am. Paint J.,* **37,** No. 22, 76, 78, 80, 82, 84 (1953) Feb. 16.

Magnesium on Air Force aircraft now painted with zinc chromate-alkyd resin primer and aluminized lacquer. Satisfactory performance is obtained when this system is exposed to normal climatic atmospheres if the magnesium is dichromate treated. Salt air, however, causes galvanic corrosion. Dichromate pretreatments reduce this corrosion tendency. In maintenance operations dichromating the magnesium is not practical. In lieu of this, a chromic acid wash prepares the magnesium for re-coating. Satisfactory adhesion cannot be obtained by this method. Wash primers, meeting Specification MIL-P-15328 contain sufficient phosphoric acid to cause blisters in the primer film due to the reactivity on the magnesium of the acid. Reducing the phosphoric acid to 25% of the amount specified in the specification produces a satisfactory coating with excellent adhesion. Decreasing the acid content of the wash primer by ageing decreases adhesion of the film to magnesium. Chrome phosphate wash primers show promise over bare magnesium, although the reduced concentration of the phosphoric acid may be the primary reason for good adhesion with severe blistering with this type of primer treatment.—ALL. 6069

6.6 Non-Metallic Materials

6.6.8

Plastic Materials of Construction. R. B. SEYMOUR. *Corrosion,* **9,** No. 5, 152-158 (1953) May.

While the major emphasis in plastics application has been in the novelty field, these materials have many chemical and physical characteristics which make them almost ideal as materials of chemical construction. In modern chemical process industry plastics are used primarily as protective coatings, linings, chemical resistant cements, joining materials and cast plastic structures. Typical applications of these materials are fairly well known but additional knowledge on corrosion resistance and physical properties is required to insure proper application. The use of reaction vessels, towers, hoods and pipe cast from filled plastics is expected to increase as additional technical information becomes available. The greatest growth industrial plastics application will be in the field of extruded, laminated and reinforced plastic materials based on plastics which are already available commercially. Considerable advances in research, design and application of such materials can be assured. This will permit the construction of chemical equipment heretofore considered impossible. 6143

6.6.8

Fluorolubes, Hooker Bulletin No. 30. Hooker Electrochemical Company, Niagara Falls, N. Y. Second Revision. February 14, 1952. 8½ x 11, paper bound, 16 pp. Available on request from the company.

Fluorolubes, fluorocarbon materials ranging from light oils to wax-like materials at room temperature, are described. The materials are credited with high temperature stability and with high resistance to many corrosive chemicals. The bulletin described in some detail the physical, dielectric and behavior characteristics of the several materials marketed under this name. 5956

6.6.8, 4.3.1, 4.4.1

Lucoflex-Solution to Corrosion in Chemical Plants. *Can. Chem. Processing,* **37,** No. 2, 62, 64-65 (1953) Feb.

Exhaust systems, self-supporting tanks, and tank liners are fabricated from hard polyvinyl chloride plastic for use in the textile industry, pulp and paper, food processing and chemical construction. This plastic, called Lucoflex on the American market, has chemical properties far superior to rubber, stainless steel and other materials used at the present time. It is non-flammable, and highly resistant to most inorganic chemicals and certain organic ones. The German polyvinyl is called Vinidur, while the one developed by the British is called Corvic L. D.—INCO. 6125

6.6.8, 7.2, 4.6.12

Glass Fiber Installed in Salt Water Disposal Wells. A. GIBBON. *World Oil,* **135,** No. 4, 203-204 (1952) Sept.

It is lightweight and can handle larger quantities of fluid. The installation of Continental Oil Company in Kansas is described. Tubing was run inside new 7 inch overall dimension steel casing which was protected from the corrosive action of the salt water by displacing the fluid in the annulus with an equal weight of naphtha. Tubing is centrifugally cast in 20 foot lengths of thermosetting plastic reinforced with glass fibers. No interior protective coating is required and thus the inside diameter if not reduced permits the pipe to handle as much as 50% more fluid. Photographs. —INCO. 5972

6.6.8, 7.2, 7.6.1

All-Plastic Materials of Construction for Corrosive Environments. J. L. HUSCHER. *Corrosion,* **9,** No. 8, 272-276 (1953) Aug.

A new group of "construction" materials — materials which can be used to fabricate processing equipment and unsupported pipe are now available to the corrosion engineer. These materials—plastics—are sometimes unknown to the corrosion engineer. The concept of plastics as self-supporting structural material for anti-corrosive applications requires familiarty with them technically and economically. While hardly a plant in the chemical and allied field does not use plastics as coatings, adhesives, linings, gaskets, etc., the use of corrosion-resistant all-plastic piping and tubing and of all-plastic chemical processing equipment is a recent development which is finding rapid acceptance. The technological and economical aspects of this group of "construction" materials are discussed. Through discriminate and proper applications—some of which are shown in illustrations—plastics are becoming extremely valuable tools in the constant fight against corrosion. 6070

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1, 3.5.9, 4.2.3, 1.3

Gas-Turbine Progress Report — Materials, Cooling, and Fuels. A. A. HAFER. Bur. Ships, Dept. of Navy. Paper before ASME, Fall Mtg., Chicago, Sept. 8-11, 1952. *Trans. Am. Soc. Mech. Engrs.,* **75,** No. 2, 127-136 (1953) Feb.

Review of improved high temperature alloys for use in gas turbines. They are tabulated with compositions and stress rupture data. The use of ceramics and ceramels are also covered. Corrosion

resulting from the presence of vanadium pentoxide, certain sodium salts and sulfur in the fuel ash is discussed. No alloy has as yet been found that will resist the vanadium attacks. It was reported that chromium-nickel steels, without other alloying elements, appear to have the best resistance to attack. Bibliography of 97 references is included.—INCO. 6109

7.2 Valves, Pipes and Meters

7.2, 4.5.1, 7.5.5

Corrosion Control—And Its Relation to Wrought Iron and Steel Piping. J. F. HIRSHFELD. The Hinchman Corp. *Official Bulletin, Heating, Piping and Air Conditioning Contractors National Association,* 60, No. 6, 31-36 (1953) June.

Encouraging recent results from corrosion control efforts have changed the engineer's attitude toward corrosion mitigation so that there is a growing activity and interest in this engineering field. Economic losses from corrosion have mounted to the point, and the losses are on such an increasing scale because of changes in technology, that it is now an economic necessity that serious efforts be made to control corrosion. In addition to direct losses, the indirect costs resulting from corrosion failures, such as lost product, shutdowns and bad public relations are of increasing magnitude. Underground corrosion of steels, because it is electrochemical in nature is amenable to control by the use of inert materials, changing the environment of the metal, by the use of barriers to the environment and by the use of impressed current. Several examples of corrosion is underground tanks and piping are reported, together with the control measures adopted. Economic aspects of cathodic protection on several types of tanks are discussed. 6115

7.7 Electrical, Telephone and Radio

7.7, 3.6.9, 5.2.1, 8.2.1

Protection of Underground Cable Sheaths. T. W. ALEXANDER, JR. Bell Telephone Co. of Penn. *Iron Steel Engr.,* **30,** No. 4, 97-100; disc. 100-102 (1953) Apr.

Causes of stray currents and the remedial measures taken to prevent corrosion of underground cable sheaths are discussed. Forced drainage or cathodic protection and use of plastic cable sheaths are suggested as preventive measures. Diagrams.—INCO. 6229

8. INDUSTRIES

8.4 Group 4

8.4.3, 5.8.2, 3.2.2

Preventing Hydrogen Attack on Steel. W. A. BONNER, H. D. BURNHAM, J. J. CONRADI (Shell Oil Co.) AND T. SKEI (Shell Dev. Co.). Paper before API, 18th Mid-Year Mtg., N. Y., May 12, 1953. *Petroleum Processing,* **8;** Nos. 5 & 6; 686-690, 878-883 (1953) May, June.

Use of modern refining processes and the handling of sour hydrocarbons have increased the vulnerability of steel equipment in refineries to attack by the atomic hydrogen released by acid corrosion of the steel. Damage through blistering

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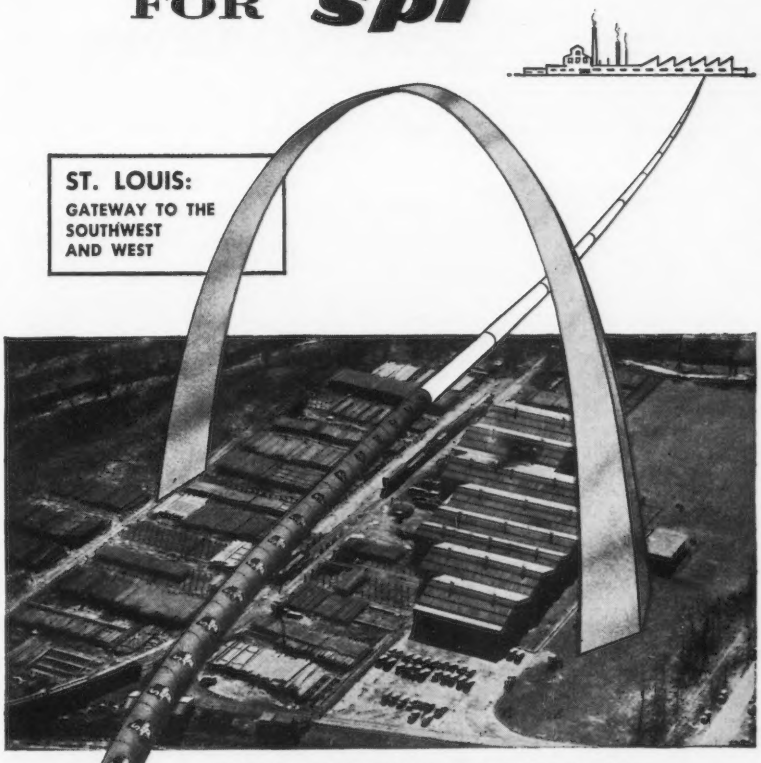

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and fissuring can be sustained when streams containing ammonia and hydrogen sulfide at a pH of 7-9 are processed. Conditions necessary for the attack to occur and methods to detect hydrogen penetration are given. New techniques for its prevention by use of ammonium polysulfide and oxygen as inhibitors are described. Graphs and 14 references.—INCO. 6223

8.4.3, 6.2.5, 3.7.2

Stainless Steels in Petroleum Refining (Oxidation Resistance). W. L. NELSON. *Oil Gas J.*, **51**, No. 39, 99 (1953) Feb. 2.

Discussion of AISI steels used in the refinery industry. Use of small amounts of carbon—usually under 0.08%—alleviates the tendency toward embrittlement of the 400 series plain chromium steel, such as types 405 and 410 which exhibit excellent resistance to oxidation. Use of nickel in amounts related to the chromium content, and small amounts of titanium or cobalt, as in stabilized types 321 and 347 give greater stability. Large amounts of nickel are not useful in steels used for refinery services because nickel is expensive and the high nickel-steels are corroded by hydrogen sulfide and sulfur dioxide. Molybdenum, as in types 316 and 317, increases resistance to creep and under certain conditions improves corrosion resistance. Effect of chromium content on resistance to oxidation for carbon steel and chromium and chemical compositions of the steels including nickel content are tabulated.—INCO. 6160

8.4.5

Metallurgy for Nuclear Reactors. J. E. BURKE. *Gen. Elec. Rev.*, **56**, 6-9 (1953) Mar.

Shows that metallurgists must deal with strength, formability, thermal conductivity, and corrosion at high temperatures when selecting materials for nuclear reactors. Cost, availiability, and interaction with neutrons must also be considered. Tables and diagrams.—MR. 6255

8.8 Group 8

8.8.1, 8.4.3

Production of Ammonium Sulfate from Refinery Waste. E. D. Fox. Fluor Corporation. Paper before ASME, Petroleum Div., Kansas City, Sept. 22-24, 1952. *Oil & Gas J.*, **51**, No. 22, 113-115, 117 (1952) Oct. 6. *Petroleum Refiner*, **31**, No. 11, 123-126 (1952) Nov.

Outline of the production of ammonium sulfate from refinery waste and description of the equipment and materials of construction required for a successful application. Type 316 stainless steel has given satisfactory service in the handling of ammonium sulfate and can be used for all vessels, process equipment and piping involved. Carbon steel proved satisfactory for the handling of acid sludge and can be used for vessels, pumps and piping in this service. Acid concentration is controlled so that corrosion from high concentrations is practically eliminated.—INCO. 5952

8.8.5

Finishing Plant Engineering. *Metal Finishing*, Guidebook-Directory Issue, 1953.

Consists of following papers: "Plating-Room Layout," J. J. Martin, Jr.; "Plating Room Floor Construction," V. A. Curll; "Mechanical Exhaust for Plating Rooms," B. F. Postman; "Choosing the Full Automatic," John V. Davis; "Essentials of Plating Rack Design," William E. Belke; "Electrical Power for Plating. I Motor-Generators," A. P. Munning; "II. Rectifiers," Philip P. Bruno; "Calculating Voltage Drops in Bus Bars," Raymond F. Ledford; "Corrosion Resistant Tanks and Linings," Paul G. McDermott; "Protective Coatings in the Plating Industry," Raymond B. Seymour; and "Control and Treatment of Metal Finishing Wastes," David Milne.—BTR. 6150

8.8 Group 9

8.9.3, 5.2.1

Hugoton Plains Gathering System 216.4 Miles Long. P. REED. *Oil Gas J.*, 51, No. 23, 191-192 (1952) Oct. 13.

Gathering system protected by coal tar enamel coating and cathodic protection. The entire coated pipe is isolated by insulation and protected by 2 rectifiers. One percent of the system consisting of bare lines is protected by magnesium anode installations.—INCO. 5886

8.9.5

Corrosion Problems in Oil Tankers. Some Methods of Protecting the Internal Surfaces of Cargo Spaces. *Petroleum Times*, **57** (1953) Jan. 23.

Corrosion of cargo tanks occurs owing to presence of water; however, white oil cargoes tend to accelerate corrosion, possibly because of cleaning and degreasing action on tank interior, which causes abnormal vulnerability to attack in presence of water, especially salt wa-

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INDEX TO ADVERTISERS

Vol. 10 May, 1954 No. 5

	Page
Allen Cathodic Protection Co.	xiv
Amercoat Corporation	Inside Front Cover
American Chemical Paint Company	25
Apex Smelting Company	6
Atlas Mineral Products Company	23
Bart Manufacturing Company	38
Barrett Division, Allied Chemical & Dye Co.	180
Brance-Krachy Company	xii
Carboline Company	17
Cathodic Protection Service	20
Cathodic Rustproofing Company	26
Coast Paint and Lacquer Co.	27
Corrosion Directory	28, 29
Corrosion Rectifying Company	4
Dow Chemical Company	ii
Duriron Company, Inc.	Inside Back Cover
Earl Paint Corporation	vii
Federated Metals Division American Smelting & Ref. Co.	11
Haynes Stellite Company, Div. Union Carbide & Carbon Corp.	xiii
Hercules Powder Company	31
Humble Oil & Refining Company	2
International Nickel Co., Inc.	vi
Johns-Manville Sales Corp.	i
Mavor-Kelly Company	5
Mayes Brothers, Inc.	24
Michigan Pipe Company	16
National Carbon Company, Div. of Union Carbide & Carbon Corp.	33
Perma-Line Rubber Products Corp.	18
Pipeline Anode Corporation	10
Pipe Linings, Inc.	x
Pittsburgh Coke & Chemical Co.	xv
Positions Wanted and Available	29
Reilly Tar & Chemical Corporation	9
Saran Lined Pipe Company	19
Service Engineers, Inc.	14
Spee-Flo Corp., The	40
Standard Magnesium Corporation	22
Standard Pipeprotection, Inc.	37
Stearns, D. E., Company	Back Cover
Tapecoat Company, The	39
Tickle, Arthur J., Engineering Works, Inc.	8
Themec Co., Inc.	34
Tretolite Company	15
Tube-Kote, Inc.	30
United States Stoneware Co.	xi
Universal Oil Products Company	13
Williamson, T. D., Inc.	35

ter. Black oil cargoes do not have this effect. Notes on corrosion occurring in ballast, and consideration of protection by organic coatings, cathodic protection, inhibitors, and dehumidification are included. Pitting of mild steel cargo heating coils in black oil ships constitutes a special problem. Cast iron coils have proved successful substitute.—INCO. 6153

8.9.5, 5.4.5, 2.2.5, 5.2.1

Examination of 335 Miles of Asphalt Mastic Coated Pipe. DONALD E. MILTNER. *Corrosion*, 9, No. 7, 210-215 (1953) July.

335 miles of continuously applied asphalt mastic coated pipe laid in 1941 has been examined by an extensive and systematic coating survey. This report outlines the methods of test employed in the examination; describes the test results, details typical coating failures found by inspection and discusses the coating behavior with particular reference to the prolonged effect of cathodic protection. 6172

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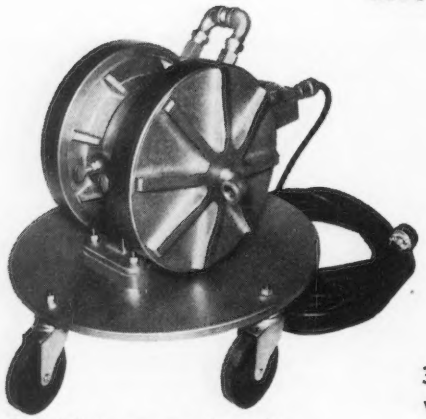

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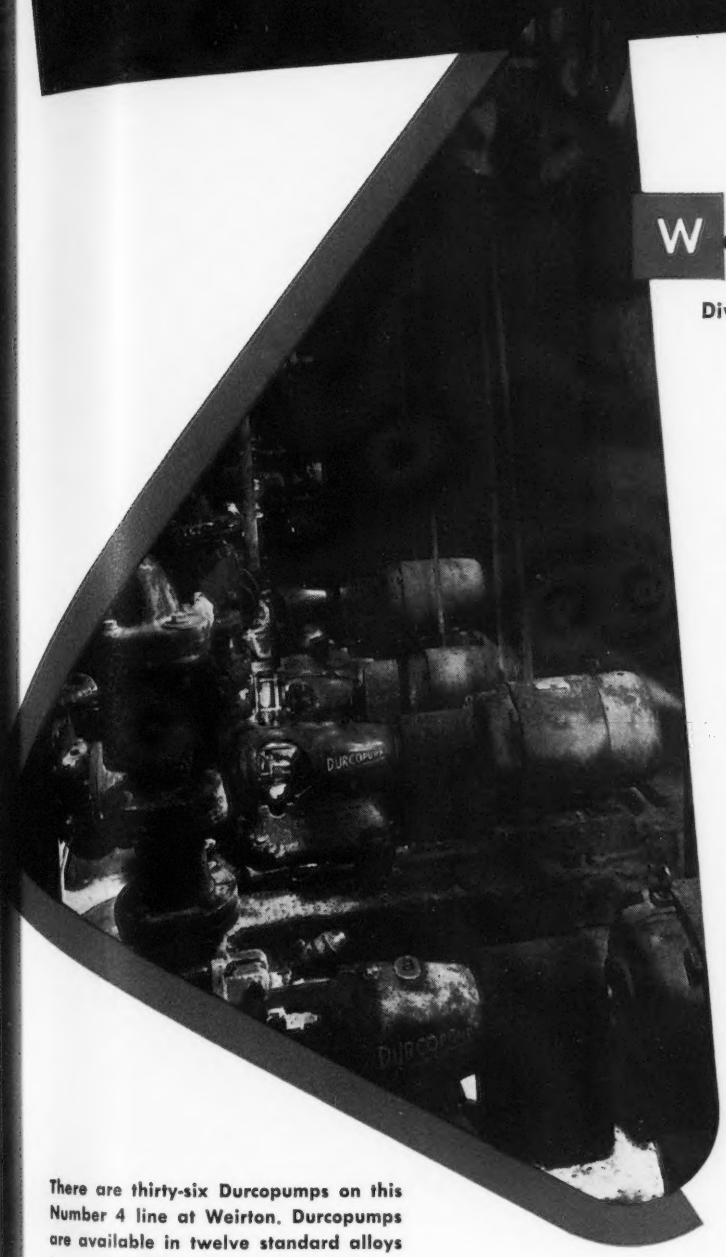

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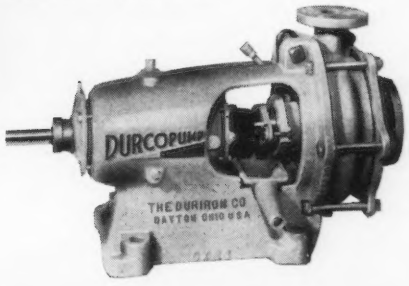

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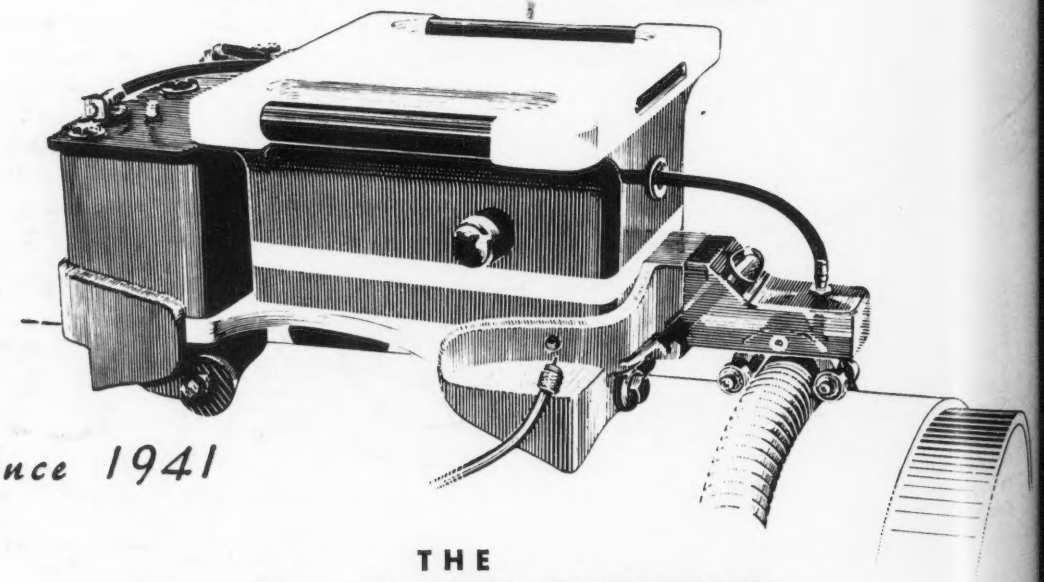

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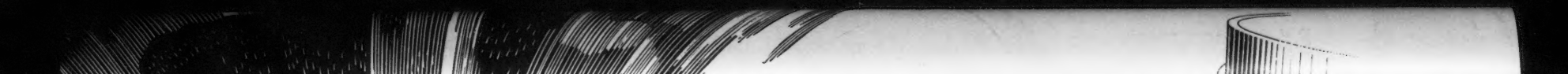
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